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AN EVALUATION OF FULL SCALE FABRIC FILTERS ON UTILITY BOILERS:
SPS Harrington Station Unit 3

by

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16. ABSTRACT

The report gives results of total mass and fractional size particulate emission tests at Southwestern Public Service's Harrington Station Unit 3 from July 8 to 11, 1981, as part of a program to evaluate and characterize the performance of full-scale fabric filter units installed on 100 MW or larger coal-fired power plants. Three outlet and one inlet mass and fractional size emission tests were performed. Due to the absence of inlet ports, inlet testing was done by bypassing the baghouse and testing at the outlet ports of the fabric filter. The fabric filter is a shake/deflate unit with 32 compartments. Each compartment has 204 bags, 30 ft 6 in. long and 11.5 in. in diameter. Design air/cloth ratio is 2.8. Average outlet concentration was 0.007 lb/million Btu. Inlet loading was 2.0 lb/million Btu, giving a 99.65% collection efficiency. Particle sizing tests indicated that the mass geometric mean diameter for the three outlet tests ranged from 7.2 to 13 micrometers, with an inlet mass diameter of 60 micrometers.

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Pollution	Combustion	Pollution Control	13B	21B
Filtration	Particles	Stationary Sources	07D	14G
Fabrics		Fabric Filters	11E	
Utilities		Particulate		
Boilers			13A	
Coal			21D	

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Abstract

The overall objective of this program was to evaluate and characterize the performance of full-scale fabric filter units installed on 100 MW or larger coal-fired power plants. This document reports results of total mass and fractional size particulate emission tests of one location. A separate report documents a similar emission test on a second site and includes operating and maintenance data from that location.

Testing was conducted at Southwestern Public Service's Harrington Station, Unit 3, between July 7, 1981, and July 11, 1981. Three (3) outlet and one (1) inlet mass and fractional size emission tests were performed. Due to the absence of inlet test ports, inlet testing was done by bypassing the baghouse and testing at the outlet ports of the stack.

Emissions for Unit 3 are controlled by two (2) baghouse systems, east and west, each with its own operating control system and by-pass dampers for start-ups, emergency operation and shutdown. This shake/deflate cleaning system consists of 32 compartments (16 in east system and 16 in west system) with 204 bags per compartment for a total of 6,528 bags.

Average outlet concentration resulted in a lower than expected value of 0.007 lbs/10^6 BTU. The loading of the inlet testing was 2.0 lbs/10^6 BTU giving a 99.65% collection efficiency for the baghouse.

Particle sizing tests indicated that the mass geometric mean diameter for the three outlet tests ranged from 7.5 to 13 μ with an inlet mass diameter of 60.2 μ.

This report was submitted in fulfillment of Contract No. 68-02-3649 by ETS, Inc. under the sponsorship of the U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Office of Research and Development.

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Great appreciation is expressed to Dale Harmon, EPA Project Officer, for his guidance and contributions to this test program. The cooperation of Richard Chambers, Olin Plunk, and Kenneth Ladd of Southwestern Public Service made this program possible.

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LIST OF ABBREVIATIONS AND SYMBOLS

1. BTU - British Thermal Units
2. °F - Degrees Fahrenheit
3. ACFM - Actual Cubic Feet per Minute
4. Oz - Ounce
5. lb/hr - Pounds per hour
6. μ - Micrometer
7. ml - Milliliters
8. CFM - Cubic Feet per Minute
9. lbs/10^6 BTU- Pounds per Million BTU
10. DSCFM - Dry Standard Cubic Feet per Minute
11. gr/ACF - Grains per Actual Cubic Feet
12. DSCF/10^6 - Dry Standard Cubic Feet per Million BTU
13. SO_2 - Sulfur Dioxide
14. O_2 - Oxygen
15. NO_2 - Nitrogen Oxide
16. CO - Carbon Monoxide
17. F Factor - A factor based on simple principles of combustion for a specific fuel used to calculate emission rates.

CONVERSION FACTORS FOR BRITISH AND METRIC UNITS

To convert from	To	Multiply by	To	Multiply by
^{o}F	^{o}C	$\frac{5}{9}$ (^{o}F-32)	—	—
ft.	meters	0.305	centimeters	30.5
ft.^{2}	meters^{2}	0.0929	centimeters^{2}	929.0
ft.^{3}	meters^{3}	0.0283	centimeters^{3}	28,300.0
ft./min. (fpm)	centimeters/sec.	0.508	meters/sec.	5.08×10^{-3}
ft.^{3}/min.	centimeters^{3}/sec.	471.9	meters^{3}/hr.	1.70
in.	centimeters	2.54	meters	2.54×10^{-2}
in.^{2}	centimeters^{2}	6.45	meters^{2}	6.45×10^{-4}
oz.	grams	28.34	grains	438.0
oz./yd.^{2}	grams/meter^{2}	33.89	grams/centimeter^{2}	3.39×10^{-3}
grains	grams	0.0647	—	—
grains/ft.^{2}	grams/meter^{2}	0.698	—	—
grains/ft.^{3}	grams/meter^{3}	2.288	—	—
lb. force	dynes	4.44×10^{5}	Newtons	0.44
lb. mass	kilograms	0.454	grams	454.0
lb./ft.^{2}	grams/centimeter^{2}	0.488	grams/meter^{2}	4880.0
in. H_2O/ft./min.	cm. H_2O/cm/sec.	5.00	Newtons/meter^{2}/cm/sec.	490.0
Btu	calories	252		

I. INTRODUCTION

EPA funded a program in 1980 to evaluate and characterize the performance of full-scale fabric filter units installed on 100 mw or larger coal-fired power plants. The program required particulate total mass and fractional size efficiency testing and collection of performance, operation, maintenance and problem information. Southwestern Public Service's Harrington Station Unit 3 was selected as one of the sites to be tested.

Test protocol followed that specified in the Federal Register. Diagrams of the stack and sampling ports may be found on pages 6 and 7. A conversion table for covering British and metric units may be found on page xi.

A total of four (4) outlet particulate total mass tests and one inlet particulate total mass test were performed. Run 1 was voided because an incorrect stack moisture content was assumed which resulted in the wrong size sampling nozzle being used. Runs 2, 3, and 5 (outlet tests) are considered valid tests. Run 4 was the inlet particulate test which was conducted by bypassing the baghouse and testing at the stack outlet ports. A summary of these test data may be found in Table 1 on page 2.

DATA SUMMARY TABLE

Southwestern Public Service, Harrington, Unit 3

Table 1

OUTLET EMISSION DATA

July 6 - 11, 1981

Run & Date	Particulate Emissions Outlet lbs/10^6 BTU	Particulate Emissions Outlet lbs/hr	Particulate Emissions Outlet gr/ACF	MW Production % Opacity	Flow Outlet ACFM DSCFM	Outlet Temp. °F	Orsat %CO_2 Inlet Outlet	Orsat %O_2 Inlet Outlet	Orsat %CO Inlet Outlet	Baghouse Differential Pressure	Stack Gas Moisture In: Out:
Run 1 7/8/81	---- VOID----										
Run 2 7/9/81	0.009	35.91	0.0024	340.5 5.5	1712460 944245	323.2	In: — Out: 11.6	In: — Out: 6.5	In: — Out: 0.0	East BH: 6.98 West BH: 6.26	In: — Out: 10.6
Run 3 7/9/81	0.009	34.55	0.0022	349.7 5.5	1737950 911922	323.2	In: — Out: 11.6	In: — Out: 6.5	In: — Out: 0.0	East BH: 8.1 West BH: 6.7	In: — Out: 14.3
Run 5 7/10/81	0.003	11.7	0.0008	349.4 5.6	1707690 938412	322.6	In: — Out: 11.6	In: — Out: 6.5	In: — Out: 0.0	East BH: 7.1 West BH: 6.6	In: — Out: 10.2

*INLET EMISSION DATA

Run & Date	Particulate Emissions Inlet lbs/10^6 BTU	Particulate Emissions Inlet lbs/hr	Particulate Emissions Inlet GR/ACF	MW Production % Opacity	Flow Inlet ACFM DSCFM	Inlet Temp. °F	Orsat %CO_2 Inlet Outlet	Orsat %O_2 Inlet Outlet	Orsat %CO Inlet Outlet	Baghouse Differential Pressure	Stack Gas Moisture In: Out:
Run 4 7/9/81	2.0	7958.5	0.5167	349.3 98.1	1777280 947257	341.0	In: 11.6 Out: —	In: 6.5 Out: —	In: 0.0 Out: —	East BH: 5.4 West BH: 4.9	In: 10.7 Out: —

*Inlet test conducted by bypassing the baghouse.

II. DESCRIPTION OF PROCESS AND CONTROL DEVICES

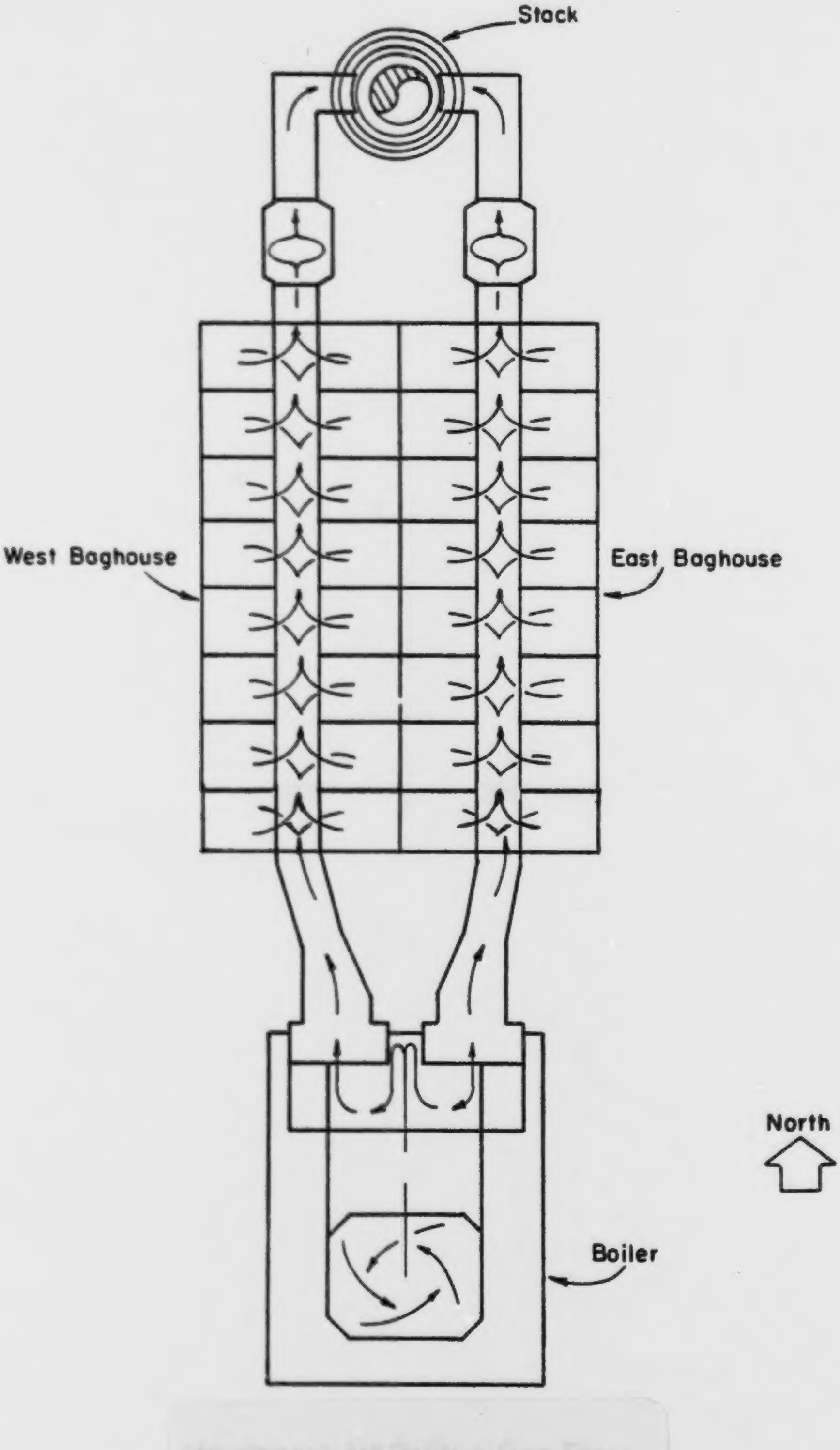
SPS's Harrington Station Unit 3 consists of a tangentially fired, Combustion Engineering steam generator, capable of producing 2,682,393 pounds of steam per hour at 2500 psig, 1005°F superheat, and 1005°F reheat.

Pulverized Western coal with average parameters of 8475 BTU/lb, 0.3% sulfur and 5.5% ash is burned.

Particulate emissions are controlled by a Wheelabrator-Frye, Inc. baghouse designed to operate at a flue gas flow of 1,650,000 ACFM at 313°F, with a minimum design efficiency of 98.6%.

There are two (2) baghouse systems at Harrington Unit 3, east and west, each with its own operating control system and bypass dampers for start-up, emergency operation and shut-down. A schematic of the boiler and baghouse configuration may be found in Figure 1.

This shake/deflate cleaning system consists of 32 compartments with 204 bags per compartment for a total of 6528 bags; each bag is 11.5 inches in diameter and 30 feet, six inches long. Bag spacing is 14.0 inches center-to-center, with a bag reach of two. Design air-to-cloth ratio is 2.81:1 gross, 2.90:1 with one compartment down and 3.0:1 with two compartments down. Total cloth area is 6.0×10^5 ft^2. The baghouse is outfitted



Harrington No. 3 Flue Gas Flow
Figure 1

with 50% 14 oz. fiberglass acid resistant coating Criswell 449I625 bags and 50% Criswell 442 570C-2 10 oz. Teflon coated fiberglass bags. All bags are of caps and eye bolts design. Three and one-half inches of fiberglass insulation covers the baghouse exterior.

Test Port Locations

Sampling was conducted at four (4) ports spaced equi-distance around a 20.8 ft. diameter stack. Three traverse points were assigned to each of the four (4) ports, resulting in a twelve (12) point traverse particulate test. Diagrams of the stack and ports may be found in Figures 2 and 3.

Test Team Personnel

The following is a list of ETS & RTI employees who participated in this testing program:

Team Member	Co.	Job Description
John Mycock	ETS	Team Leader
John Richardson	ETS	Boiler & Baghouse Control Rooms
Carlos Pareja	RTI	Weigher
Shannon Delaney	ETS	Impactor Operator
Jeff Smith	ETS	Outlet Test Leader
Richard Ferron	ETS	Outlet Probe
Dave Ensor	RTI	Quality Assurance Leader

SPS Personnel On Site

Richard Chambers	Project Engineer - Fabric Filters

Figure 2

Harrington Unit 3
Stack Configuration

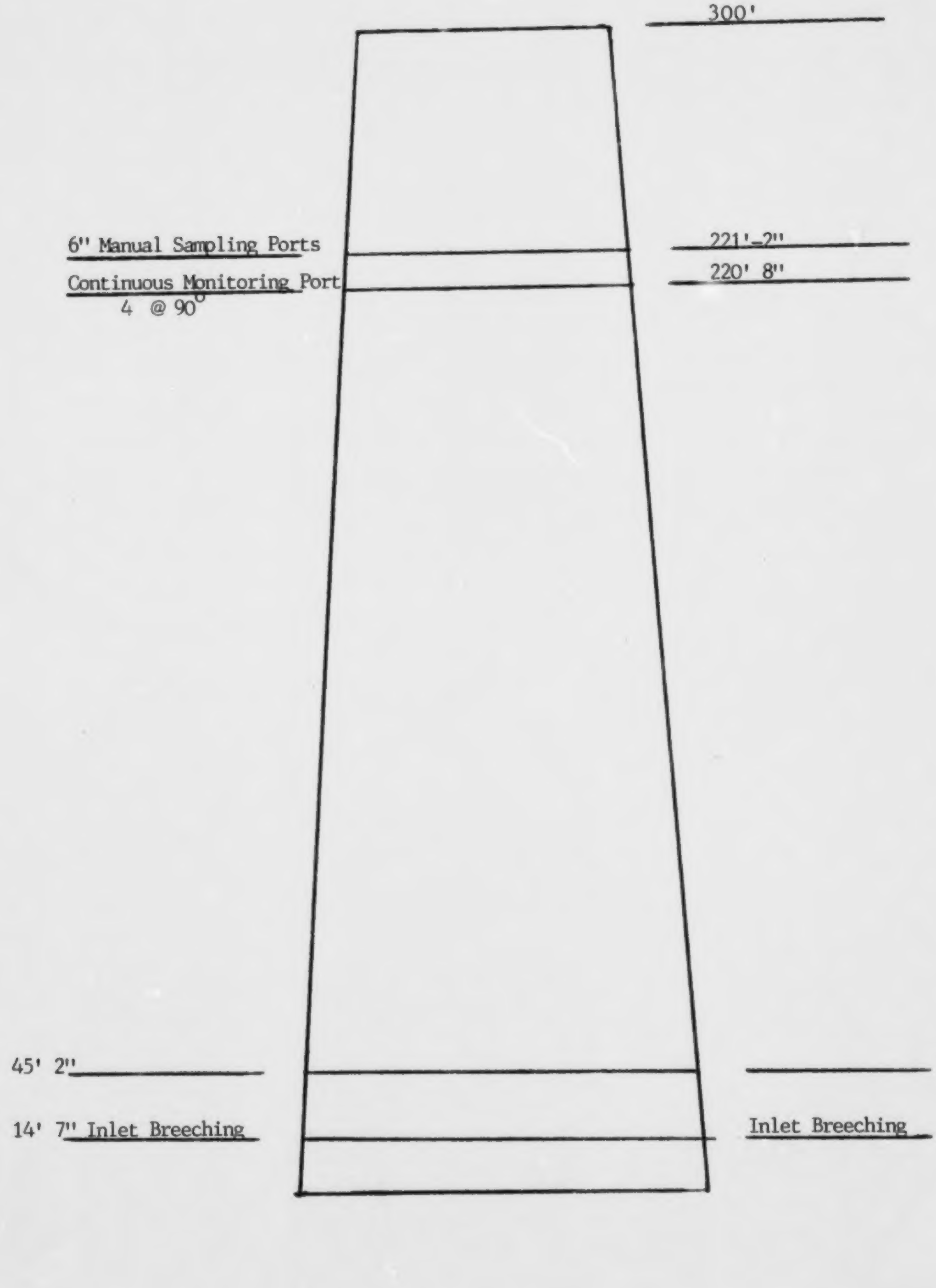
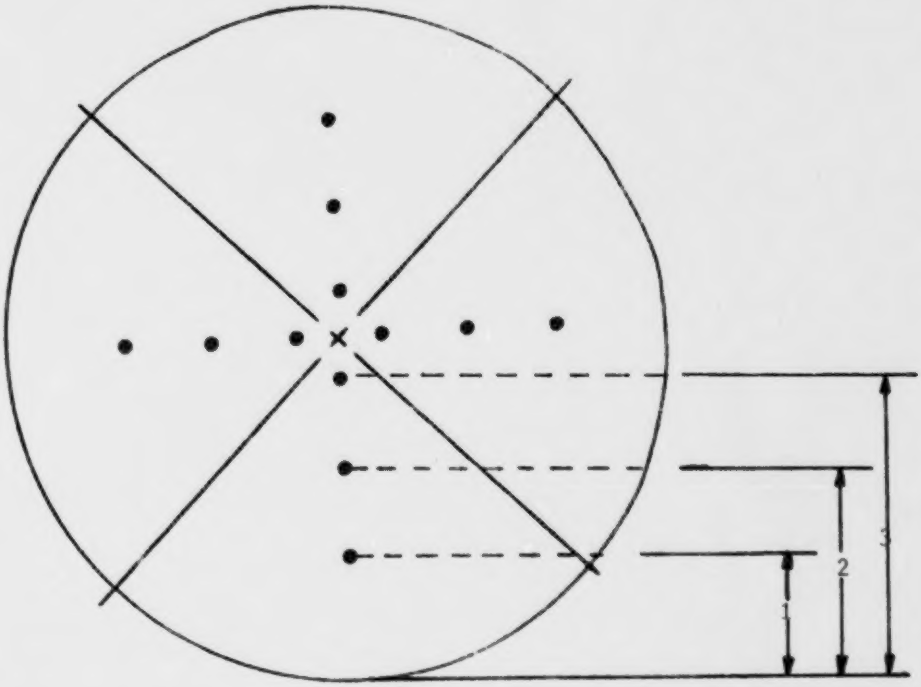


Figure 3

Traverse Points

Harrington Unit 3



Traverse Pt.	Distance in Inches
1	56.3
2	81.8
3	119.2

Testing Methodology

Particulate emission tests were conducted according to U.S. EPA Reference Method 5 procedures in conjunction with Methods 1, 2, 3 and 4. Each test included a 12-point traverse with a ten (10) minute sampling duration for each point.

Assembly and use of the impactor train followed state-of-the-art protocol and general Method 5 sampling train procedures. Special precaution was taken to avoid rough handling of loaded impactors, overloading of the impactor and in the performance of hot leak tests.

Test 4 was an inlet particulate test conducted by bypassing the baghouse and directing the particulate directly to the outlet stack. Due to the expected high loading rate during the inlet test, test 4 incorporated EPA Method 17. A Norten AN-899 5.0 μ retention alundum thimble was used in this test.

Sampling Equipment and Procedures

Particulate-(Reference: Method 17, CFR-Title 40, Part 60, Appendix A)

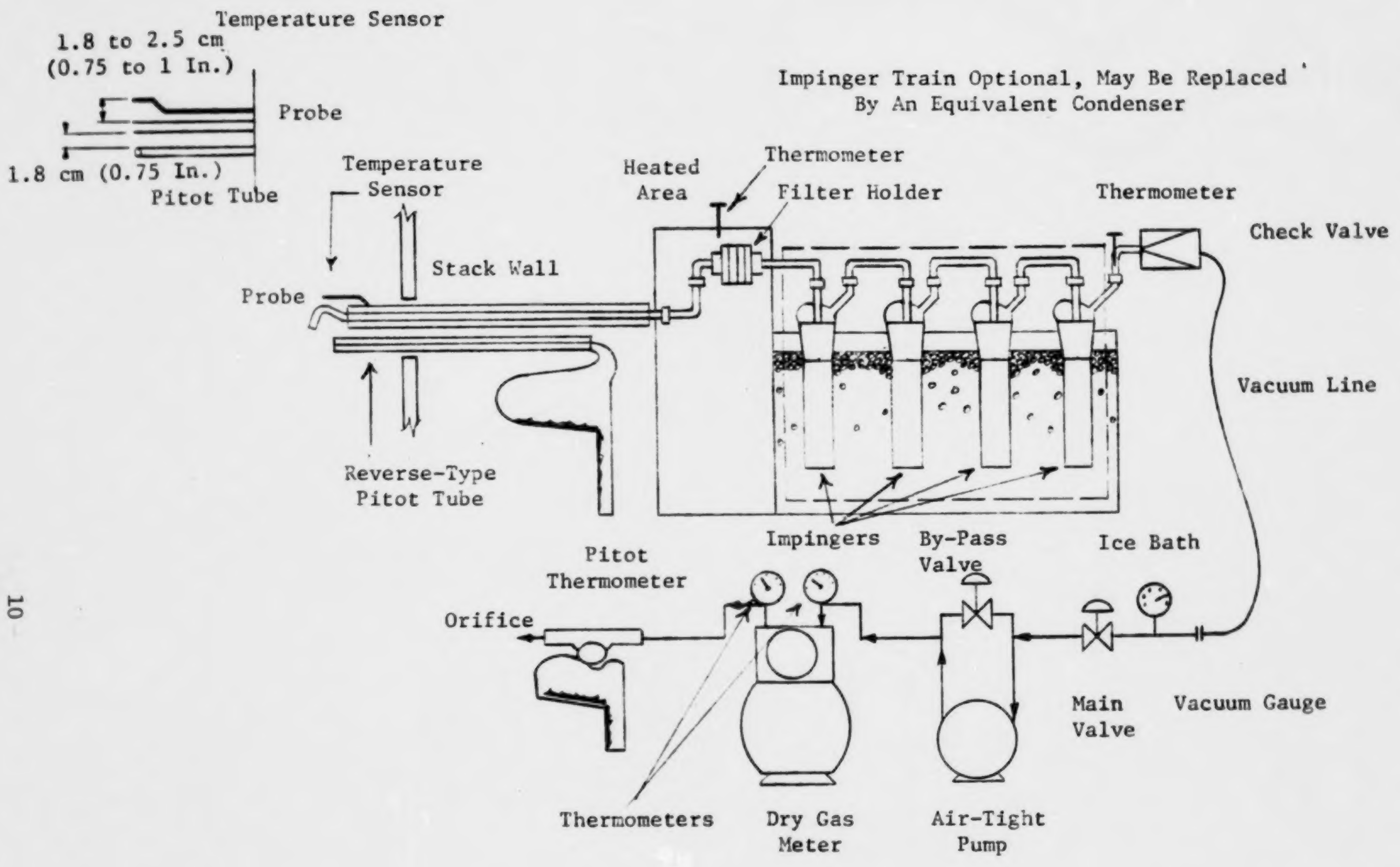
The particulate sampling equipment used is referred to as the "EPA Particulate Sampling Train", designed and developed by EPA (formerly the National Center for Air Pollution Control, Public Health Service, Department of Health, Education and

Welfare). The "train" used in this testing was assembled by ETS, Inc. in accordance with current construction details published by EPA. A schematic of the sampling train is shown in Figure 4.

The apparatus consists of a stainless steel sampling nozzle, a Method 5 filter holder containing an 87 millimeter Schleicher and Scherell #1 - HV High Purity Glass Filter, a series of four (4) Greenburg-Smith impingers, a check valve, a leakless vacuum pump, a dry gas meter, and a calibrated orifice. The impingers and connecting tubes are made of pyrex glass and are connected with glass ball and socket joints. The probe is made of type 316 stainless steel.

The first, third, and fourth impingers are modified by replacing the high velocity tip with a glass tube having an inside diameter of 1/2 inch. The first and second impingers are charged initially with 100 ml of water. The third impinger is left dry, and the fourth impinger is charged with approximately 200 grams of dry, pre-weighed silica gel. All four impingers remain packed in an ice bath during sampling.

Using the Type "S" pitot tube, a velocity traverse is performed along all traverse axis during each particulate run. The velocity pressure at each sampling point is measured by means of an inclined manometer. A thermocouple is also attached to the pitot tube to measure gas stream temperature. Thermal potential is measured with an Omega portable potentiometer.



Method 5 Sampling Train
Figure 4

Before beginning a run, the complete sampling train including probe and nozzle is leak tested by plugging the nozzle with a rubber stopper and then applying a vacuum of 15 inches of mercury to the system. This procedure is repeated at the conclusion of each run. The maximum allowable leakage rate of 0.02 cfm was not exceeded in any of the leak tests.

During testing, isokinetic sampling conditions are achieved by maintaining the velocity of the stack gas entering the sampling nozzle equivalent to the stack gas velocity at each sampling point. The required velocity of the stack gas entering the sampling nozzle is obtained by adjusting the pressure drop across the calibrated orifice. The pressure differential across the calibrated orifice is measured by an inclined/vertical manometer with an inclined range of 0-1.0 inches of water and vertical range from 1.0 to 10.0 inches of water. The proper calibrated orifice pressure drop is determined by using reproductions of the nomographs contained in the publication, "Addendum to Specifications for Incinerator Testing at Federal Facilities".

At the completion of each test; the sampling nozzle, inside of the probe, inside of the thimble holder and front-half of the glass fiber filter holder were washed with acetone. The washings were collected in separate storage containers. The alundum thimble and the glass fiber filter were removed from their respective filter holders and stored in separate storage containers. The contents of the first three impingers were measured and discarded. The silica gel from the fourth impinger was transferred to a separate storage container. All storage containers were returned to the laboratory for analyses.

Tests to determine carbon dioxide, oxygen and carbon monoxide were conducted via an Orsat analysis according to EPA Method 3.

Particulate test calculations such as flue gas volume, flue gas velocity, and percent isokinetics were performed using a computer. These data may be found in Appendix 9.

III. SUMMARY OF RESULTS

A summarization of the particulate emission tests performed at Southwestern Public Service, Harrington Station Unit 3 may be found in Table 1. The average particulate emission rate for the three (3) outlet tests conducted by Method 5 was 0.007 lbs/10^6 BTU. Test 4, the Method 17 inlet test, resulted in an emission rate of 2.0 lbs/10^6 BTU. These results indicated that the baghouse collected 99.65% of the particulate.

A total of four (4) impactor tests were conducted, one during each of the three (3) outlet tests and one during the inlet test. The mass mean diameter for the three (3) outlet tests varied from 7.5 to 13.0 μ.

IV. DISCUSSION OF RESULTS

During this test series, there were no deviations from normal operating conditions for Unit 3 that could be determined from the control room or baghouse control room data or conferences with the boiler operators. Control room data monitored during the test period compared closely with previous data.

Data related to flue gas measurements such as flue gas volumes, orsat measurements, percent moisture and molecular weights may be found in Appendix 9. Flue gas volumes for the three (3) outlet and one inlet particulate tests were within an expected and consistent range.

Appendix 3 contains strip charts taken from SPS's baghouse control room during this test series. Strip charts monitoring ash discharge, SO_2, O_2 and NO_x concentrations, percent opacity, baghouse outlet temperature and pressure drop are included.

Inlet and outlet moisture measurements were also consistent with expected concentrations with the exception of Run 3. Runs 2, 4, and 5 averaged 10.5 percent moisture compared to 14.3 percent for Run 3.

Emission rates in $lbs/10^6$ BTU were calculated using average F factors derived from coal analysis performed on SPS coal.

Emission rates and associated calculations are in Table 2.

Proximate fuel analyses of coal samples taken during each of the particulate tests were performed by Norfolk Testing Laboratories in Norfolk, VA. Approximately five pound integrated coal samples were taken from the coal bunkers during each test, of which approximately one-half pound was analyzed for ash, sulfur, moisture and BTU content. Coal parameter concentrations remained within the expected and design range with the exception of moisture content of the coal sample taken during Run 4. Tabulated lists of the coal analyses may be found in Appendix 6.

After comparing previous ash analysis with the analysis made on the ash generated during this test series, it was concluded that little difference existed between the typical coal burned and the coal burned during this testing project. The coal burned at Southwestern Public Service Co. is a typical western coal, high in calcium and silica, mined from the Powder River Basin near Gillette, Wyoming.

As stated earlier in the results summary section, outlet particulate emissions at Harrington Unit 3 as determined by Method 5 averaged 0.007 lbs/10^6 BTU. Emission rates are also expressed in lbs/hr and averaged 27.39 lbs/hr for the three (3) outlet tests. The single inlet emission test performed by bypassing the baghouse resulted in an emission rate of 2.0

TABLE 2

F-Factor Calculations for Runs 2-5

SPS - Harrington Station Unit 3

$$E = Cs\ Fd\ \left(\frac{20.9}{20.9-\%O_2}\right)$$

where Cs = pollutant concentration in lb/DSCF

Fd = F-factor in DSCF/10^6 BTU

O_2 = percent O_2 in stack gas

E = emissions in lbs/10^6 BTU

Run 2 $$E = \frac{6.3 \times 10^{-7}\ \text{lb}}{\text{DSCF}} \left| \frac{9700\ \text{DSCF}}{10^6\ \text{BTU}} \right| \frac{20.9}{20.9-6.5} = 0.009\ \text{lbs}/10^6\ \text{BTU}$$

Run 3 $$E = \frac{6.3 \times 10^{-7}\ \text{lb}}{\text{DSCF}} \left| \frac{9700\ \text{DSCF}}{10^6\ \text{BTU}} \right| \frac{20.9}{20.9-6.5} = 0.009\ \text{lbs}/10^6\ \text{BTU}$$

Run 5 $$E = \frac{2.1 \times 10^{-7}\ \text{lb}}{\text{DSCF}} \left| \frac{9700\ \text{DSCF}}{10^6\ \text{BTU}} \right| \frac{20.9}{20.9-6.5} = 0.003\ \text{lbs}/10^6\ \text{BTU}$$

*Run 4 $$E = \frac{1.4 \times 10^{-4}\ \text{lb}}{\text{DSCF}} \left| \frac{9700\ \text{DSCF}}{10^6\ \text{BTU}} \right| \frac{20.9}{20.9-6.5} = 2.0\ \text{lbs}/10^6\ \text{BTU}$$

* Inlet test performed by bypassing the baghouse

lbs/10^6 BTU or 7958.5 lbs/hr. Emission rates for outlet Runs 2 and 3 were very close at 0.009 lbs/10^6 BTU (35.9 lbs/hr), and 0.009 lbs/10^6 BTU (34.6 lbs/hr) respectively, while outlet run 5 resulted in an unexpected low emission rate of 0.003 lbs/10^6 BTU or 11.7 lbs/hr. The inlet run performed at the outlet stack ports also resulted in a lower emission rate than expected when compared to previous test results conducted at SPS Harrington Unit 3. Emission rates for the Method 5 and impactor tests are compared in Table 3.

Temperature measurements for the three (3) outlet tests were very consistent, not varying more than 1°F. These data may be found in Table 1 and Appendix 2. Temperature measurements taken by the test crew at the stack compared well with those measured at the baghouse outlet. Stack temperatures for tests 2, 3, and 5 averaged 323°F and baghouse outlet temperatures averaged 334°F.

Cascade impactor sampling was performed under the supervision of Research Triangle Institute, July 8 and 9, 1981. Impactor results may be found in Appendix 5 as a separate report. Three (3) outlet and one (1) inlet impactor tests were performed. Figure 5 summaries the cumulative mass size distribution results for the three (3) outlet impactor tests.

The particle size data based on impactor tests is of questionable reliability. All outlet impactor tests including a blank showed

TABLE 3

GRAIN LOADING FROM METHOD 5 AND IMPACTOR TESTS

SPS - Harrington Unit 3

July 8 - 11, 1981

Run & Date	Impactor Loading Rates	Method 5 Particulate Loading
Outlet Run 1 7/8/81	0.0004 Gr/ACF	VOID
Outlet Run 2 7/8/81	--	0.0024 Gr/ACF
Outlet Run 3 7/9/81	0.0007 Gr/ACF	0.0022 Gr/ACF
Outlet Run 5 7/10/81	0.0015 Gr/ACF	0.0008 Gr/ACF
*Inlet Run 4 7/9/81	1.06 Gr/ACF	0.5167 Gr/ACF

*Inlet test performed by bypassing the baghouse

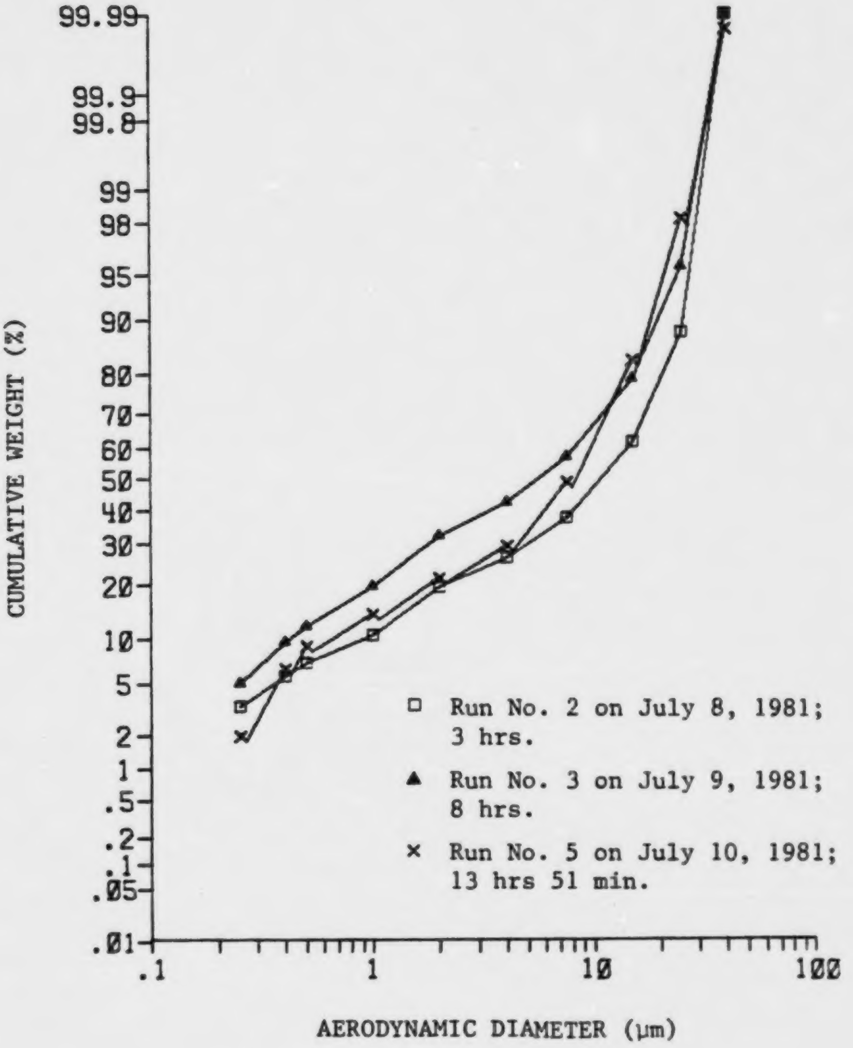


Figure 5 Cumulative mass size distribution for three outlet impactor samples.

sampled weight losses in spite of extended sampling times. The weight losses on the substrates were believed to be due to chemical reactions of the flue gas with the grease to form volatile materials. The Harrington flue gas must have some unusual trace reactive gases because the Apiezon-H grease had performed satisfactorily at other test sites. All of the outlet size distribution data were adjusted using the blank test substrate weight losses. It is recognized that the weight corrections are arbitrary, and other approaches could be used. The corrections are described in detail in Appendix 5.

Bag analyses were performed at ETS' laboratory in Roanoke, VA. The entire battery of tests were performed including permeability, tensile strength, MIT flex and Mullen Burst. A total of four (4) bags (2 used and 2 new) were tested. These data are depicted in Appendix 7.

Overall, the bag analyses done by ETS, Inc. indicate a greater percentage loss of strength in terms of MIT flex, Mullen Burst and tensile strength than preivous tests performed by Environmental Consultant Company. Permeability as received is essentially the same when comparing ETS's and ECC's results. The cleaning procedures differ between the two laboratories, but in general, indicate approximately the same permeability improvement after cleaning. A more detailed comparison of the bag analyses of ETS and ECC may be found in Table 4.

TABLE 4 - FABRIC TESTING RESULTS COMPARISON

Bag Type	Fabric Tests				Testing Co.
	Flex (Fill)*	Mullen Burst	Tensile	Permeability	
Acid Resistent (625) Used	Top - 48 Middle - 55 Bottom - 68	13 - 29% loss	Fill - 0-20% Warp - 1-17%	As received - 1.48-2.75 After wash - 48	ECC
	Top - 58 Middle - 57 Bottom - 71	32% loss	Fill - 43% Warp - 31%	As received - 1.2-2.1 After vacuum - 60.4	ETS, INC.
Teflon - B Used	Top - 59 Middle - 50 Bottom - 49	2 - 20% loss	Fill - 0-16% Warp - 0-7%	As received - 2.31-2.75 After wash - 55	ECC
	Top - 84 Middle - 88 Bottom - 89	24% loss	Fill - 18% Warp - 27%	As received - 1.8-2.0 After wash - 46.4	ETS, INC.
Acid Resistent (625) New	Fill - 2,500 Warp - 12,500	700 PSI	Fill - 300 Warp - 600		ECC
	Fill - 3,013 Warp - 10,400	619 PSI	Fill - 252 Warp - 465		ETS, INC.
Teflon - B New	Fill - 500 Warp - 15,000	525 PSI	Fill - 130 Warp - 250		ECC
	Fill - 629 Warp - 9,946	343 PSI	Fill - 87 Warp - 228		ETS, INC.

*ECC- .03 jaws @ 4 lbs.
ETS - .04 jaws @ 8 lbs.

Test	Measurement Parameters
MIT Flex -	cycles
Mullen Burst -	lbs/sq. inch
Tensil -	lbs/inch
Permeability -	CFM/sq. ft.

It should be noted that ETS used a .04 jaw and four (4) pound weight and ECC used a .03 jaw and four (4) pound weight when performing the MIT flex test. Another possible contributing factor to the results differences is that the ECC bag testing was done in April 1981 and the ETS bag analyses were performed in September, 1981, thus the bags were on stream longer before the ETS tests were conducted.

Laboratory analytical procedures incorporated are those mandated by the Federal Register Part II, Environmental Protection Agency, Revision to Reference Methods 1-8. These procedures may be found in Appendix 1.

APPENDIX 1

Cascade Impactor Testing Protocol

CASCADE IMPACTOR SUBSTRATE AND FILTER PREPARATION

I. Glass Fiber Substrates

A. Foils should be cut to hold substrates, each substrate and foil cup placed inside a petri dish, labeled and organized into run numbers.

B. Glass fiber substrates are known to exhibit anomalous weight gains due to sulfate uptake of the substrates. In order to correct this problem, substrates must be preconditioned in the flue gas before weighing. The preconditioning can be done using a thimble with a prefilter holder. The preconditioning is outlined as follows:

   1. Where sampling times are short and mass loadings are heavy, 2 to 6 hours.

   2. Up to 24 hours to eliminate sufficient sulfate uptake and weight gains where sampling times are long and mass loading is low.

C. The preconditioned substrates are then dessicated and weighed every 6 hours in their prelabeled foil cup to a constant weight.

D. Reeve Angel 934AH is usually the preferred filter material.

II. Metal-Greased Substrates

A. Preparation of substrates:

   1. Spread a grease-toluene mixture (5% Apiezon H by weight, or 10 to 20% Apiezon L by weight) with a fine hair brush. Be careful so that none of the brush hairs adhere to the substrate.

   2. Greased substrate should be tacky but not slippery with a film thickness about equal to the diameter of particles which are to be captured.

   3. Bake in the oven at 149° C (300° F) for 4 hours.

   4. Dessicate for 12 to 24 hours. (If possible weigh to a constant weight every 6 hours.)

   5. Place weighed and dessicated substrates in prelabeled petri dishes.

B. Organize dishes into run numbers.

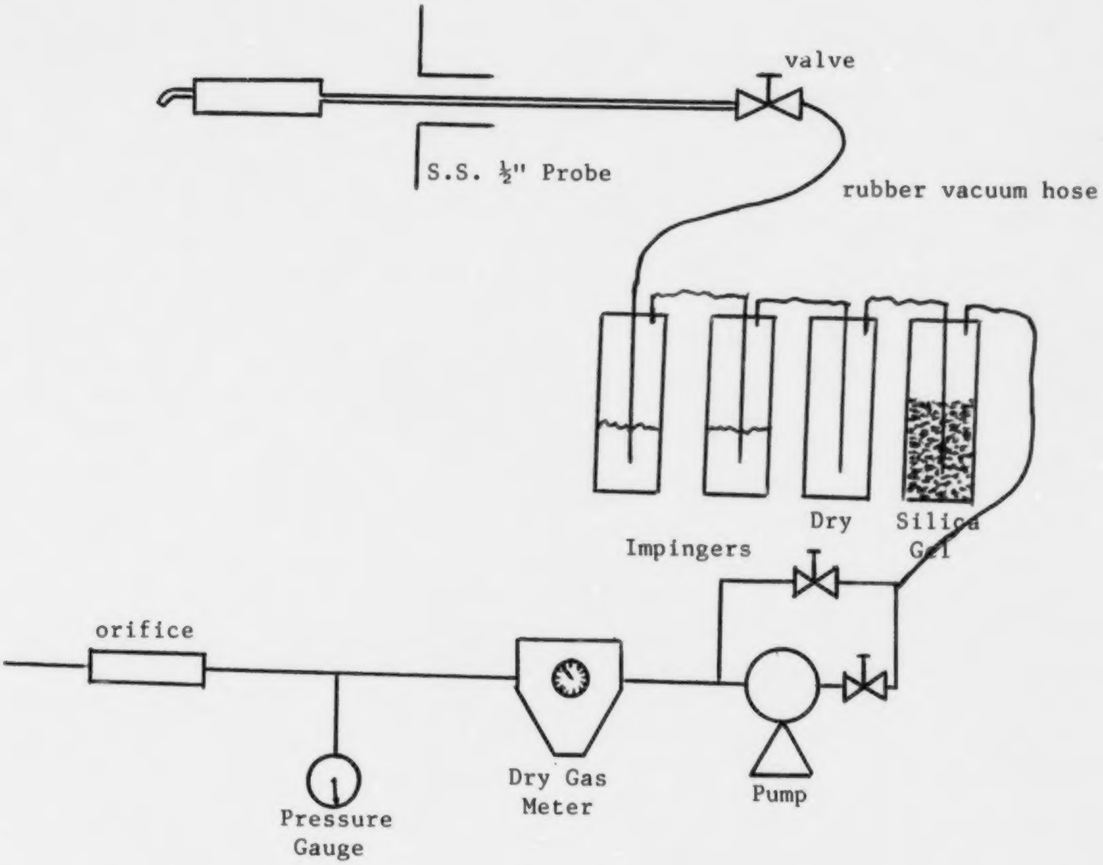
III. Filters

Backup filters made of fiberglass have problems similar to that of glass fiber substrates, such as anomalous weight gains when in contact with flue gases. The same preconditioning procedure as was applied to the glass fiber substrates is followed. Again, Reeve Angel 934AH is the preferred filter material.

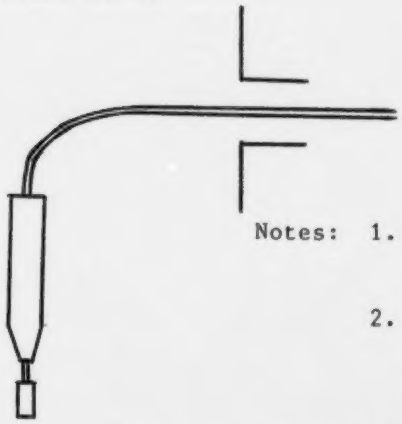
CASCADE IMPACTOR TEST PROTOCOL

1. Impactor components must be clean.
   a. Wash components in ultrasonic cleaner, if available.
   b. Visually check cleanliness. Jet holes and side walls must be clean.
2. Determine stack sampling parameters.
   a. Traverse points (Method I).
   b. Velocity distribution (Method II).
   c. Dry gas molecular weight (Method III).
3. Select a nozzle size based on stack velocity to maintain isokinetic sampling; attach nozzle to impactor.
4. Apply Teflon tape to impactor threads; this will minimize leakage. Load the impactor with preweighed substrates. Use Teflon or Kaptan gaskets on both sides of filters.
5. It is important to keep all openings on the impactor and sampling probe sealed with duct tape, aluminum foil, or any other material to prevent particulate contamination of the substrates during transportation to the test area.
6. Transport the impactor and impinger train to the test site. Assemble the sampling train as shown in Figure 1.
7. On the test site a pretest hot and cold leak check and a post-test leak check are required. The following steps outline a leak check procedure.
   a. Plug the impactor entrance with Teflon or duct tape; an alternative is to seal the entrance of the impactor with a stainless steel plug. Leak check the system, remove the plug, and install the nozzle.
   b. Close the coarse adjust valve; fully open the bypass valve; and start the pump.
   c. Partially open the coarse valve and close the bypass valve until the desired vacuum is reached (≈ 10 in. Hg).
   d. When the leak check is complete, slowly remove the plug from the inlet to the impactor and immediately turn off vacuum pump.
   e. The maximum leak rate shall not exceed 0.02 cfm (0.00057 m^3/min) or 4% of average sampling rate (whichever is less).

A) Straight Probe



B) Curved Probe



Notes:
1. The impactor may be wrapped with heating tape to maintain impactor temperature.
2. The fourth impinger must contain at least 250 gm. On long runs the silica gel can be increased to 500 gm.

FIGURE 1. Impactor Train

8. Clean out the sampling port to prevent particulate matter from accidentally entering the impactor. Place the impactor in the gas stream with the nozzle entrance pointing downstream if a stainless steel plug is not used to seal shut the entrance to the impactor. Leave the impactor inside the stack for 45 minutes so that it will be heated to stack temperature. Hot leak check the impactor following the leak check procedure described above. If a stainless steel plug has been used, remove the plug from the impactor entrance and install a nozzle after the leak check.

9. Reinsert the impactor into the stack with the nozzle pointing downstream and record the initial volume of the dry gas meter. Turn on the pump with the coarse adjust valve closed and the bypass valve open. Quickly point the nozzle downstream, open the coarse adjust valve, and set the orifice ΔP to calcualted isokinetic rate.

10. Always check for isokinetic rates by recording the volume at prespecified intervals of time.

11. When the predetermined sampling time is reached:

    a. Shut or close coarse adjust valve and valve on probe, if one exists.

    b. Make sure the bypass valve is fully opened.

    c. Shut off the pump and turn impactor downstream.

    d. Remove the impactor from the gas stream.

    e. Leak check the impactor and record leak rate.

    f. Disassemble impactor train, close off all openings, and transfer the probe and impinger train assembly to the cleanup area. The cleanup area should be clean and protected from the wind so that chances for contaminating or losing the sample are minimized.

12. When the impactor has cooled enough to disassemble:

    a. Brush away any loose particulate onto the next substrate below where the particulate is found.

    b. Place substrates in labeled identifying petri dishes.

    c. Carefully remove the filter from the filter holder and place it in its identifying petri dish. Transfer any fiber that adheres to the filter holder surface using a sharp edged knife.

    d. Place substrates and filters in a dessicator and dessicate overnight.

13. Wash the inside of the nozzle with acetone, let the acetone drain from the lower end into a preweighed cup. Let the cup air dry. When completely dry, record weight.

14. Impinger train:

    a. Impinger water--make a notation of any color change or liquid film that is in the liquid catch. Measure the liquid in the first 3 impingers to the nearest 1 ml using a graduated cylinger.

    b. Weight the silica gel in the fourth impinger and record the weight to the nearest 0.5 gm.

15. Clean impactors with soap and water in an ultrasonic cleaner, if available.

16. Clean out impingers and reload them to save time the next day.

SUBSTRATE WEIGHING PROCEDURES

1. The amount of zero and span dirft will be recorded for every set.
2. The balance will be checked with the reference substrate and weight recorded. If the weight does not repeat within 0.03 mg, there is something wrong with the balance.
3. There will be a control substrate with every set that will be weighed pre- and post-test.
4. Fiberglass substrates and filters shall be weighed inside their prelabeled aluminum foil cup.
5. There will be a weighing audit of substrates that have been used in the tests after the test has been completed.
6. A blank test shall be performed daily, if possible, to determine the effect of the flue gases on the substrates.
7. Careful record keeping should be maintained. A bound notebook with all weighings and observations entered on dated pages.

IMPINGER TRAIN PREPARATION

The impinger train consists of 4 impingers and is used to determine the moisture content of a stack gas. It is also useful in protecting the sampling equipment that can be damaged by stack condensate fluids (i.e., dry gas meter, vacuum pump). The preparation of the impinger train is outlined as follows:

1. Impinger No. 1 -- 100 ml of water.
2. Impinger No. 2 -- same.
3. Impinger No. 3 -- empty.
4. Impinger No. 4 -- 200 to 300 g of preweighed silica gel.

Care should be taken to ensure that the silica gel is not entrained during sampling. Make sure the impinger train is filled with ice once it is at the sampling site. This is a precaution to keep the pump from overheating. The bath temperature of the impinger train should be maintained at 68° F (20° C).

OTHER SAMPLING EQUIPMENT

1. Barometer -- capable of measuring atmospheric pressure to within 2 to 5 mm Hg (0.1 in. Hg).
2. Hygrometer -- to measure relative humidity of the laboratory environment.

APPENDIX 2

Control Room Data

CONTROL ROOM DATA
Run 2 - 7/9/81
SPS Harrington Unit 3

Description	Units	9:35AM	10:05AM	10:35AM	11:05AM	11:35AM	Avg.
Coal BTU Content	B/LB	8668.2	8668.2	8668.2	8668.2	8668.2	8668.2
Total Inst Coal Flow	TPH	184.1	184.1	184.8	185.9	184.9	184.8
Main Stream Flow - Measured	K#/HR	2473.0	2478.3	2466.2	2479.0	2478.0	2474.9
Inst Gross Generation	MW	349.7	349.0	349.8	349.7	349.3	349.5
Preheater Gas Out Temp - E	DEG-F	349.2	347.7	343.2	343.1	342.6	345.2
Preheater Gas Out Temp - W	DEG-F	342.8	340.7	338.2	338.8	339.8	340.1
Baghouse Outlet Temp - East	DEG-F	-.3	-.2	-.2	-.2	-.2	VOID
Baghouse Outlet Temp - West	DEG-F	327.1	327.1	324.7	323.3	323.9	325.2
East BH Diff Pressure	IN/WC	6.9	7.2	7.1	6.8	7.2	7.0
West BH Diff Pressure	IN/WC	6.2	6.5	6.4	6.2	6.4	6.3
Opacity of Flue Gas	%	5.4	5.7	5.6	5.5	5.5	5.5
SO_2 in Flue Gas	PPM	355.2	371.1	361.2	359.6	351.3	359.7
NO_x in Flue Gas	PPM	267.2	276.3	266.7	256.7	267.4	266.9
Stack Outlet Percent O_2	%	5.9	5.9	5.9	5.9	6.0	5.9

CONTROL ROOM DATA
Run 3 - 7/9/81
SPS Harrington Unit 3

Description	Units	3:36PM	4:06PM	4:36PM	5:06PM	5:36PM	Avg.
Coal BTU Content	B/LB	8681.6	8767.0	8718.0	8715.2	8720.6	8720.5
Total Inst Coal Flow	TPH	186.7	185.6	185.4	185.8	186.3	185.0
Main Stream Flow - Measured	K#/HR	2505.9	2484.5	2506.0	2502.3	2473.0	2494.3
Inst Gross Generation	MW	349.8	349.7	349.7	349.6	349.3	349.6
Preheater Gas Out Temp - E	DEG-F	349.7	343.2	341.8	343.2	344.1	344.4
Preheater Gas Out Temp - W	DEG-F	359.5	351.0	349.0	351.2	352.8	352.7
Baghouse Outlet Temp - East	DEG-F	-.1	-.2	-.2	-.1	-.2	VOID
Baghouse Outlet Temp - West	DEG-F	342.1	340.5	338.5	338.1	339.0	339.6
East BH Diff Pressure	IN/WC	10.6	6.9	6.7	7.0	6.7	7.6
West BH Diff Pressure	IN/WC	7.1	6.6	6.6	6.3	6.6	6.6
Opacity of Flue Gas	%	5.6	5.5	5.5	5.2	5.3	5.4
SO_2 in Flue Gas	PPM	349.7	349.0	367.0	358.0	341.8	353.1
NO_x in Flue Gas	PPM	249.0	250.3	258.5	259.3	263.9	256.2
Stack Outlet Percent O_2	%	5.9	6.1	6.1	6.1	6.0	6.1

CONTROL ROOM DATA
Run 4 - 7/9/81
SPS Harrington Unit 3

Description	Units		10:06PM	10:36PM	11:06PM		Avg.
Coal BTU Content	B/LB		8700.5	8722.0	8832.5		8751.7
Total Inst Coal Flow	TPH		182.5	184.7	184.8		184.0
Main Stream Flow - Measured	K#/HR		2485.3	2456.2	2466.2		2469.2
Inst Gross Generation	MW		349.2	349.5	349.3		349.3
Preheater Gas Out Temp - E	DEG-F		350.5	352.9	352.4		351.9
Preheater Gas Out Temp - W	DEG-F		350.0	351.5	349.6		350.4
Baghouse Outlet Temp - East	DEG-F		-.2	-.2	-.2		VOID
Baghouse Outlet Temp - West	DEG-F		340.9	341.7	341.2		341.3
East BH Diff Pressure	IN/WC		5.8	3.5	5.4		4.9
West BH Diff Pressure	IN/WC		4.7	3.5	5.2		4.5
Opacity of Flue Gas	%		99.6	99.9	94.8		98.1
SO_2 in Flue Gas	PPM		346.6	333.6	327.8		336.0
NO_x in Flue Gas	PPM		284.4	266.4	267.7		272.8
Stack Outlet Percent O_2	%		6.2	6.2	6.0		6.1

CONTROL ROOM DATA
Run 5 - 7/10/81
SPS Harrington Unit 3

Description	Units	11:04AM	11:34AM	12:04PM	12:34PM		Avg.
Coal BTU Content	B/LB	8607.1	8637.5	8663.4	8677.2		8646.3
Total Inst Coal Flow	TPH	189.1	186.3	185.7	185.5		186.7
Main Stream Flow - Measured	K#/HR	2499.7	2505.6	2503.4	2488.6		2499.3
Inst Gross Generation	MW	349.1	349.7	349.2	349.9		349.5
Preheater Gas Out Temp - E	DEG-F	340.7	344.8	345.0	345.7		344.1
Preheater Gas Out Temp - W	DEG-F	351.6	354.3	351.9	352.5		352.6
Baghouse Outlet Temp - East	DEG-F	-.2	-.0	-.2	-.1		VOID
Baghouse Outlet Temp - West	DEG-F	334.3	335.3	336.4	336.2		335.6
East BH Diff Pressure	IN/WC	7.1	7.1	6.9	7.1		7.05
West BH Diff Pressure	IN/WC	6.7	6.7	6.8	6.8		6.75
Opacity of Flue Gas	%	5.6	5.8	5.5	5.6		5.6
SO_2 in Flue Gas	PPM	337.1	340.7	326.0	321.4		331.3
NO_x in Flue Gas	PPM	267.2	269.0	270.1	265.4		267.9
Stack Outlet Percent O_2-	%	6.5	6.3	6.2	6.3		6.3

APPENDIX 3

Baghouse Control Room Data

Appendix III

Baghouse Control Room Data

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Ash Discharge.................................. 42

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Pressure Drop.................................. 61

Residual and Terminal Pressure Drop
West Baghouse - SPS Harrington Unit 3
Runs 2, 3, & 5 - Compartments 1-16

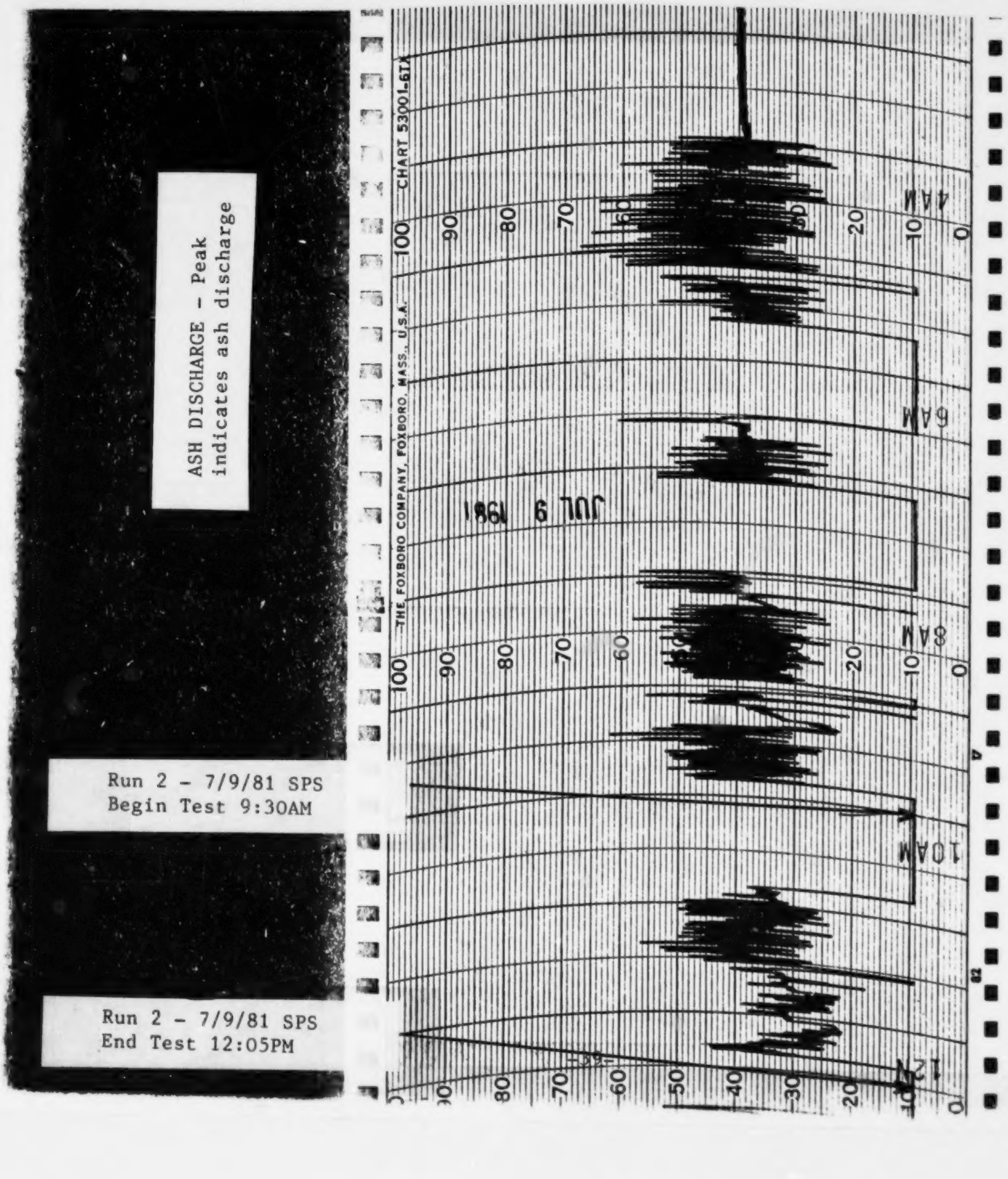
BH Compt. No.	ΔPr ΔPt	Test 2	Test 3	Test 5	Tests
1	ΔPr	5.4	5.7	5.6	
	ΔPt	6.1	6.5	6.4	
2	ΔPr	5.6	5.9	6.1	
	ΔPt	6.2	6.4	6.5	
3	ΔPr	5.85	5.9	5.9	
	ΔPt	6.1	6.4	6.45	
4	ΔPr	5.6	5.9	6.0	
	ΔPt	5.85	6.5	6.3	
5	ΔPr	5.1	5.3	5.45	
	ΔPt	5.5	6.0	6.0	
6	ΔPr	5.55	5.7	5.9	
	ΔPt	5.8	6.3	6.1	
7	ΔPr	4.8	4.9	5.5	
	ΔPt	5.2	5.7	5.8	
8	ΔPr	5.2	5.4	5.5	
	ΔPt	5.4	5.7	5.9	
9	ΔPr	4.9	5.2	5.5	
	ΔPt	5.6	5.8	5.8	
10	ΔPr	4.95	5.35	5.3	
	ΔPt	5.1	5.5	5.6	
11	ΔPr	4.7	5.2	5.3	
	ΔPt	5.25	5.6	6.0	
12	ΔPr	5.1	5.2	5.6	
	ΔPt	5.3	5.7	6.05	
13	ΔPr	4.65	4.95	5.2	
	ΔPt	5.2	5.6	5.7	
14	ΔPr	4.7	5.0	5.45	
	ΔPt	5.1	5.5	5.6	
15	ΔPr	4.75	5.2	5.4	
	ΔPt	5.15	5.65	5.65	
16	ΔPr	4.7	5.1	5.5	
	ΔPt	5.05	5.4	5.55	
Avg.	ΔPr	5.097	5.369	5.575	5.347
	ΔPt	5.494	5.891	5.963	5.783

Where: ΔPr = Residual Pressure Drop
ΔPt = Terminal Pressure Drop
BH = Baghouse

Residual and Terminal Pressure Drop
East Baghouse - SPS Harrington Unit 3
Runs 2, 3, & 5 - Compartments 17-32

BH Compt. No.	ΔPr ΔPt	Test 2	Test 3	Test 5	Tests
17	ΔPr	6.1	5.5	5.6	
	ΔPt	6.4	6.2	5.8	
18	ΔPr	6.3	6.1	6.2	
	ΔPt	6.5	6.6	6.6	
19	ΔPr	5.8	5.55	5.6	
	ΔPt	6.2	6.2	5.9	
20	ΔPr	5.75	5.9	5.7	
	ΔPt	6.3	6.2	6.0	
21	ΔPr	5.8	5.9	5.9	
	ΔPt	6.1	6.3	6.1	
22	ΔPr	6.1	6.5	6.7	
	ΔPt	6.6	6.8	6.7	
23	ΔPr	6.3	6.45	6.3	
	ΔPt	6.5	6.6	6.65	
24	ΔPr	5.3	5.4	5.2	
	ΔPt	5.5	5.95	5.9	
25	ΔPr	5.1	5.3	5.5	
	ΔPt	5.55	5.8	5.9	
26	ΔPr	5.3	5.5	5.55	
	ΔPt	5.6	5.9	5.9	
27	ΔPr	5.2	5.3	5.6	
	ΔPt	5.7	5.95	5.9	
28	ΔPr	5.8	6.0	6.0	
	ΔPt	6.0	6.5	6.1	
29	ΔPr	5.1	5.45	5.25	
	ΔPt	5.6	5.5	5.5	
30	ΔPr	5.4	5.5	5.45	
	ΔPt	5.6	5.9	5.65	
31	ΔPr	5.05	5.2	5.2	
	ΔPt	5.6	5.6	5.55	
32	ΔPr	5.5	5.7	5.7	
	ΔPt	5.7	6.1	5.8	
Avg.	ΔPr	5.619	5.703	5.716	5.679
	ΔPt	5.986	6.13	5.953	6.023

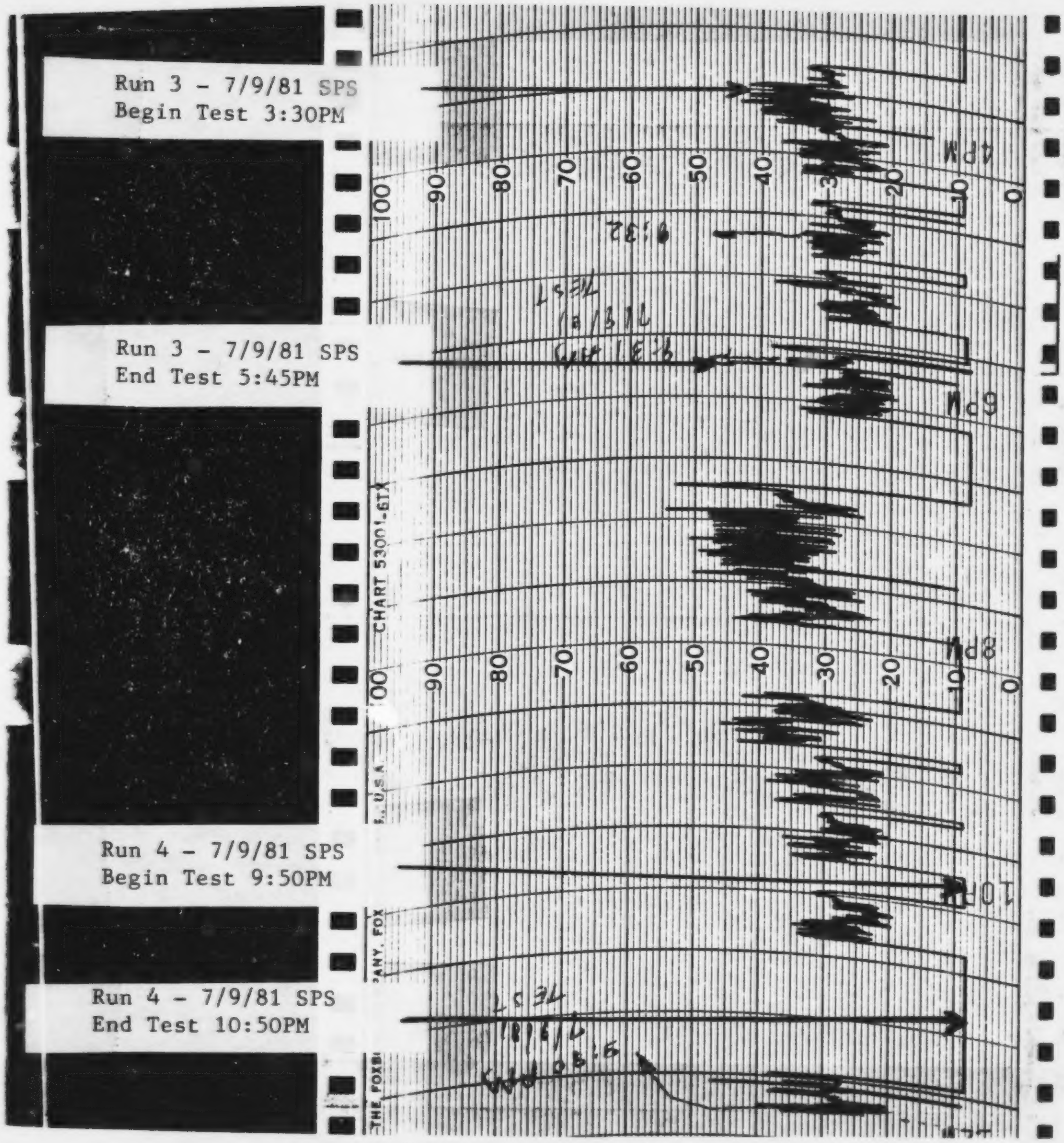
Where: ΔPr = Residual Pressure Drop
ΔPt = Terminal Pressure Drop
BH = Baghouse



ASH DISCHARGE - Peak indicates ash discharge

Run 2 - 7/9/81 SPS
Begin Test 9:30AM

Run 2 - 7/9/81 SPS
End Test 12:05PM

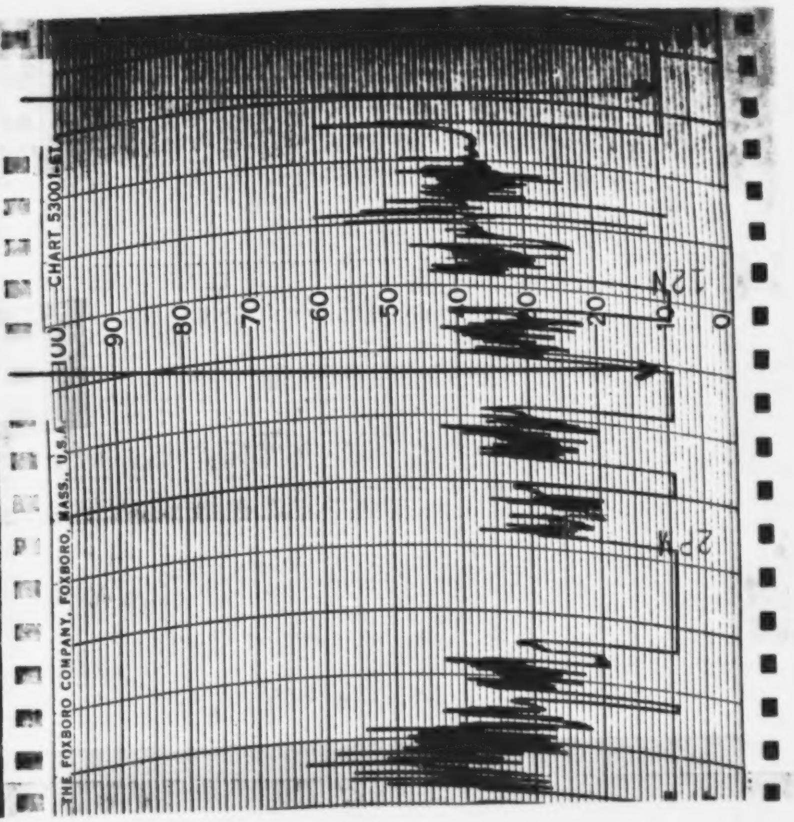


Run 3 - 7/9/81 SPS
Begin Test 3:30PM

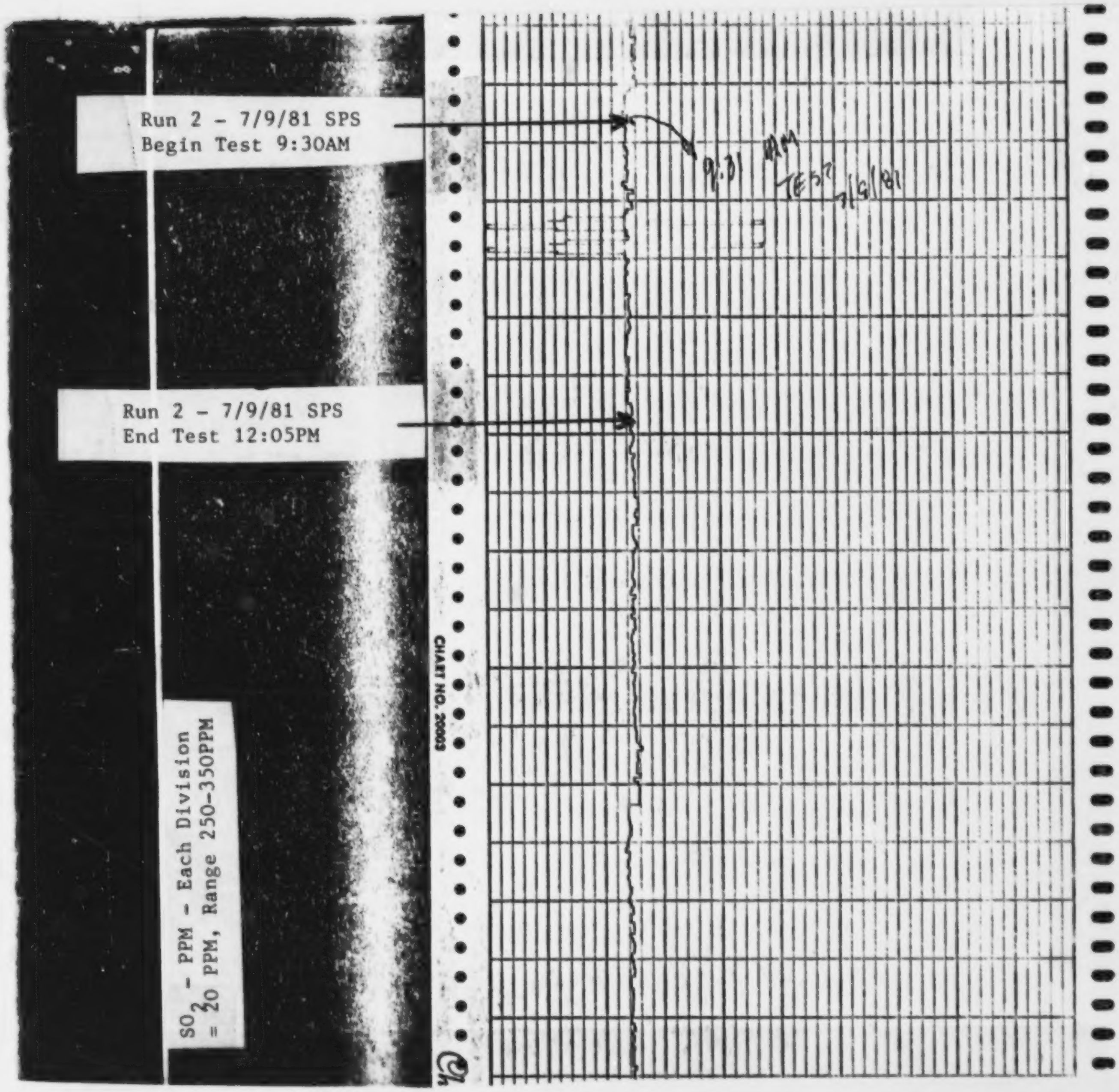
Run 3 - 7/9/81 SPS
End Test 5:45PM

Run 4 - 7/9/81 SPS
Begin Test 9:50PM

Run 4 - 7/9/81 SPS
End Test 10:50PM


Run 5 - 7/10/81 SPS
Begin Test 10:20AM

Run 5 - 7/10/81 SPS
End Test 12:35PM

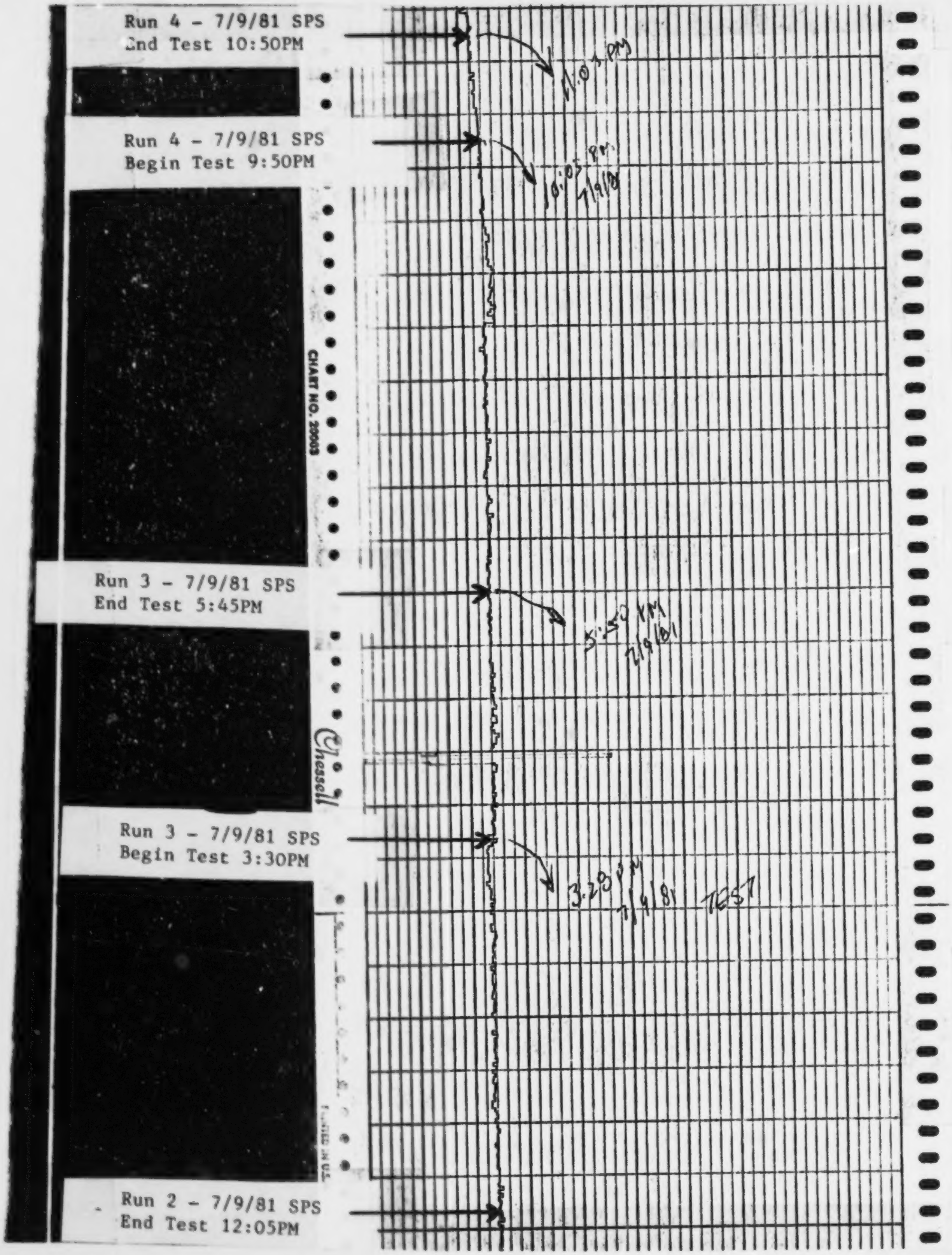


Run 2 - 7/9/81 SPS
Begin Test 9:30AM

9:31 AM TEST 7/9/81

Run 2 - 7/9/81 SPS
End Test 12:05PM

SO_2 - PPM - Each Division
= 20 PPM, Range 250-350PPM



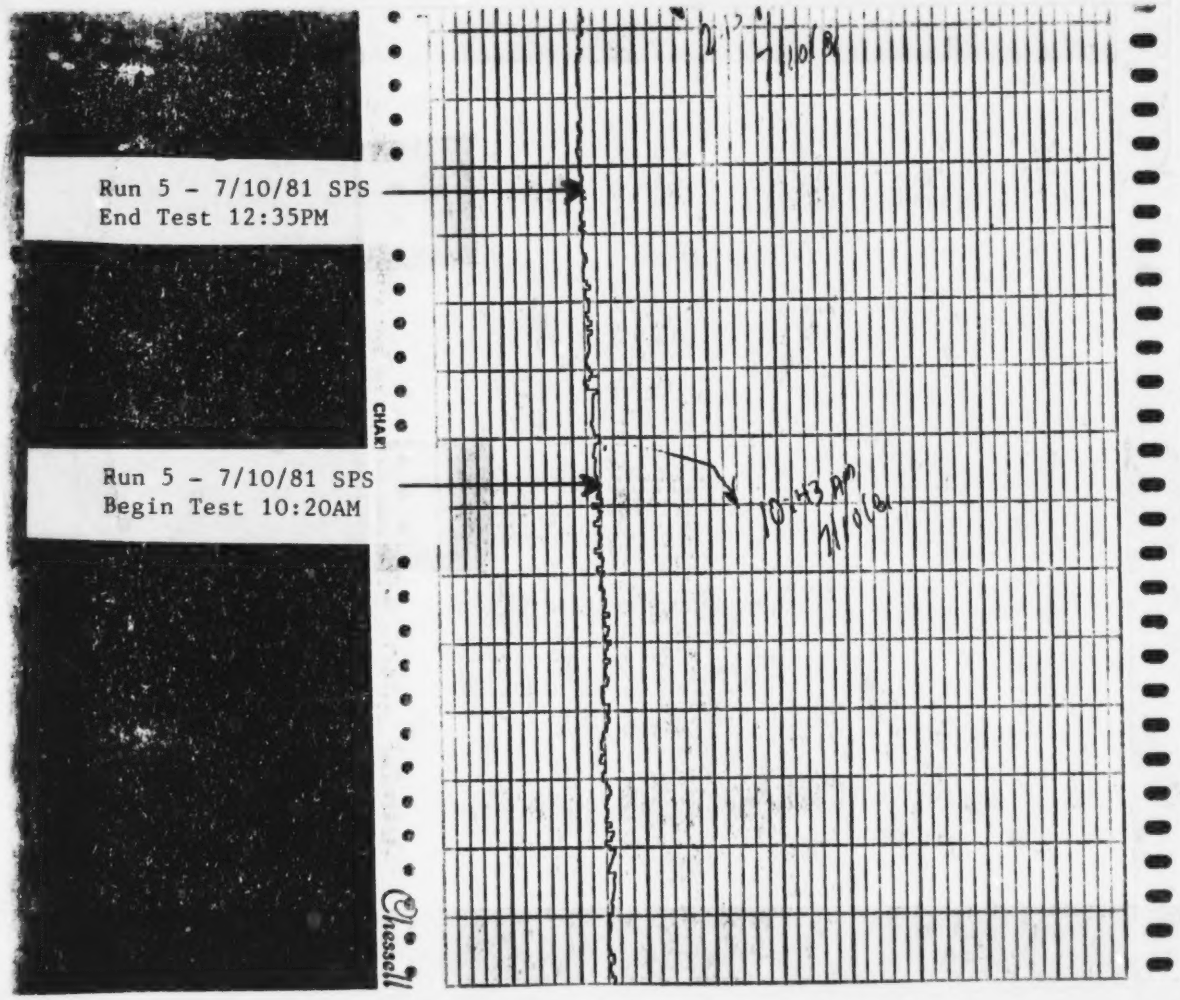
Run 4 - 7/9/81 SPS
End Test 10:50PM

Run 4 - 7/9/81 SPS
Begin Test 9:50PM

Run 3 - 7/9/81 SPS
End Test 5:45PM

Run 3 - 7/9/81 SPS
Begin Test 3:30PM

Run 2 - 7/9/81 SPS
End Test 12:05PM

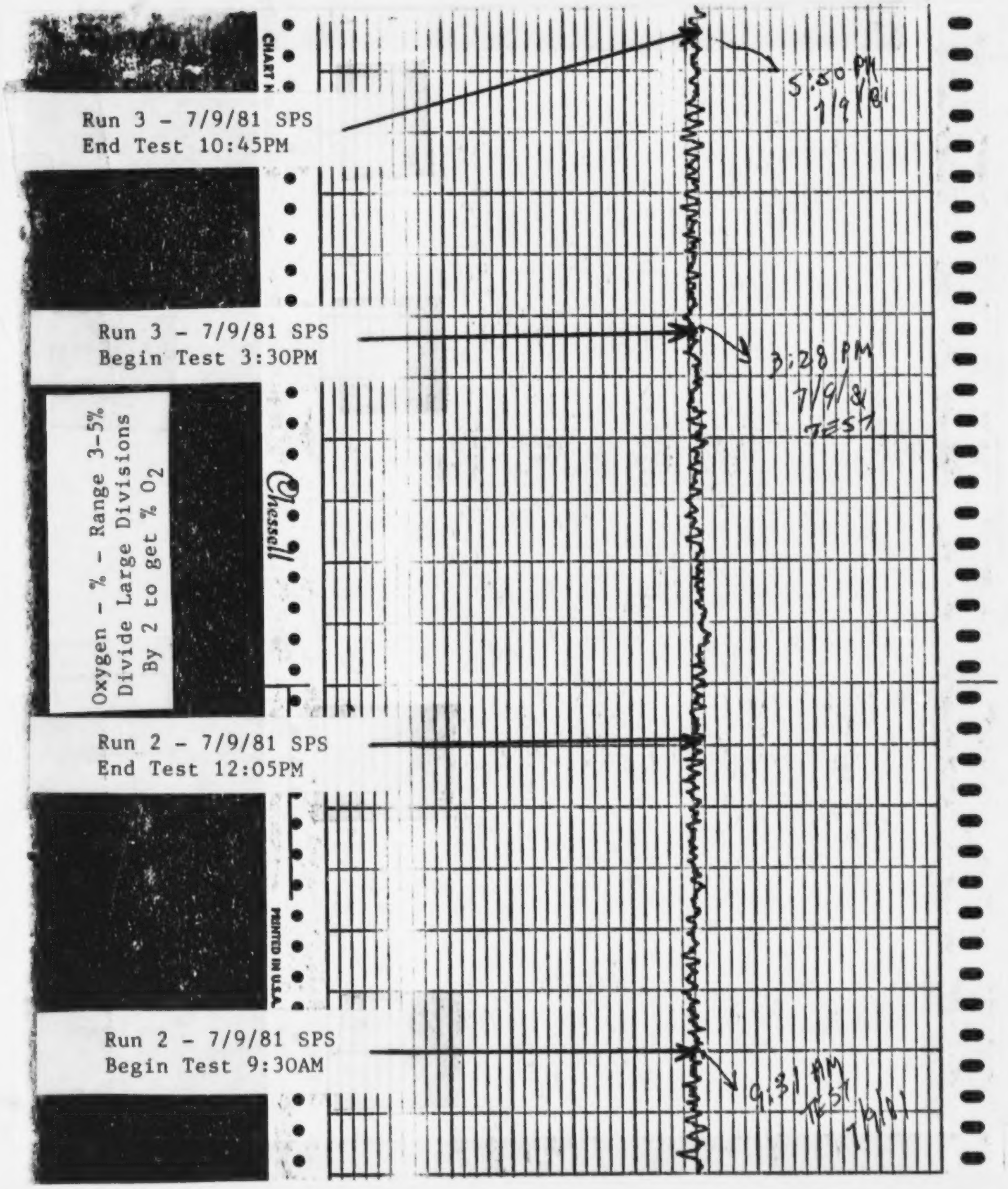


Run 5 - 7/10/81 SPS
End Test 12:35PM

Run 5 - 7/10/81 SPS
Begin Test 10:20AM

[illegible] 7/10/81

10:43 AM
7/10/81



Run 3 - 7/9/81 SPS
End Test 10:45PM

5:50 PM
7/9/81

Run 3 - 7/9/81 SPS
Begin Test 3:30PM

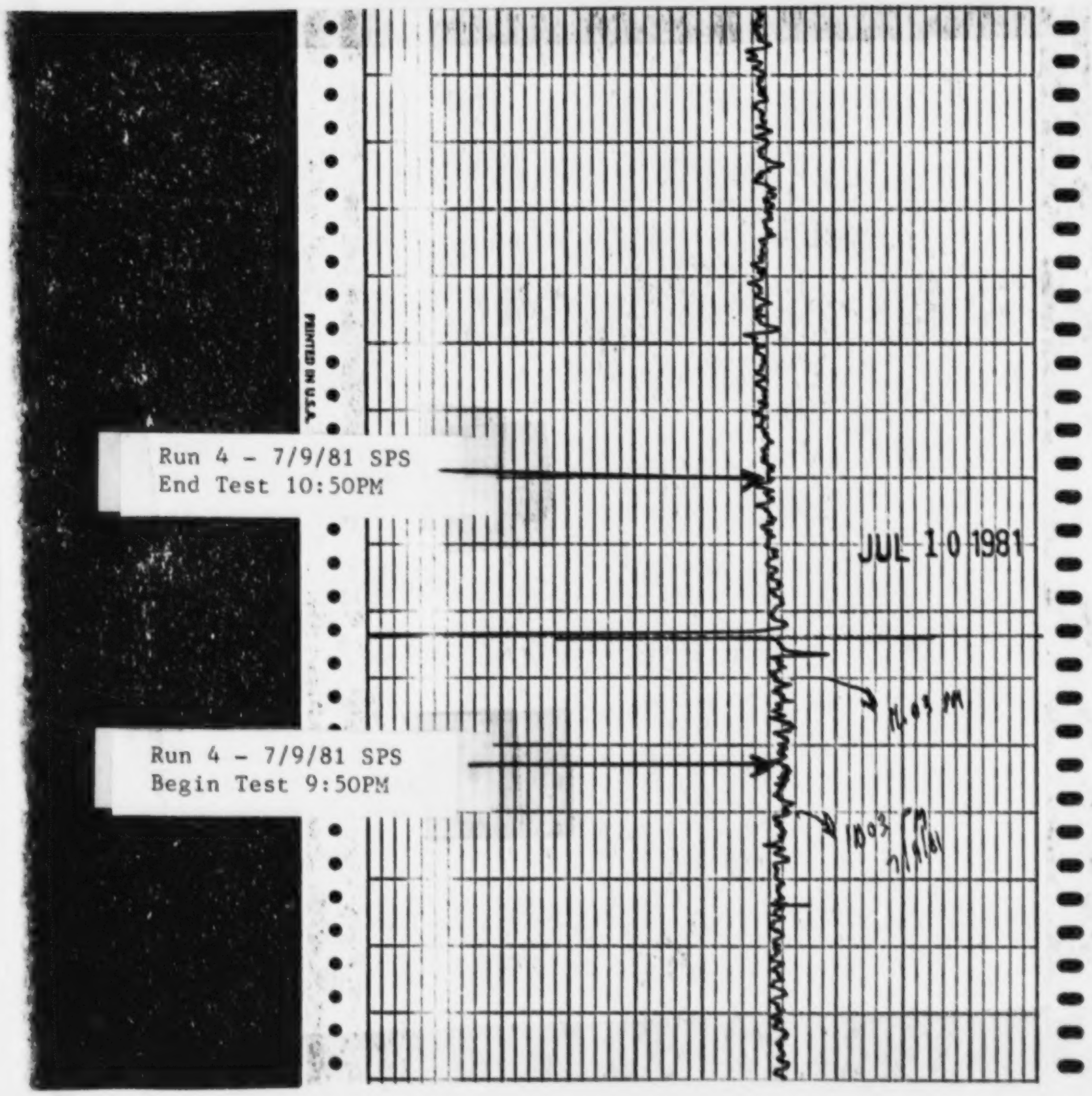
3:28 PM
7/9/81
TEST

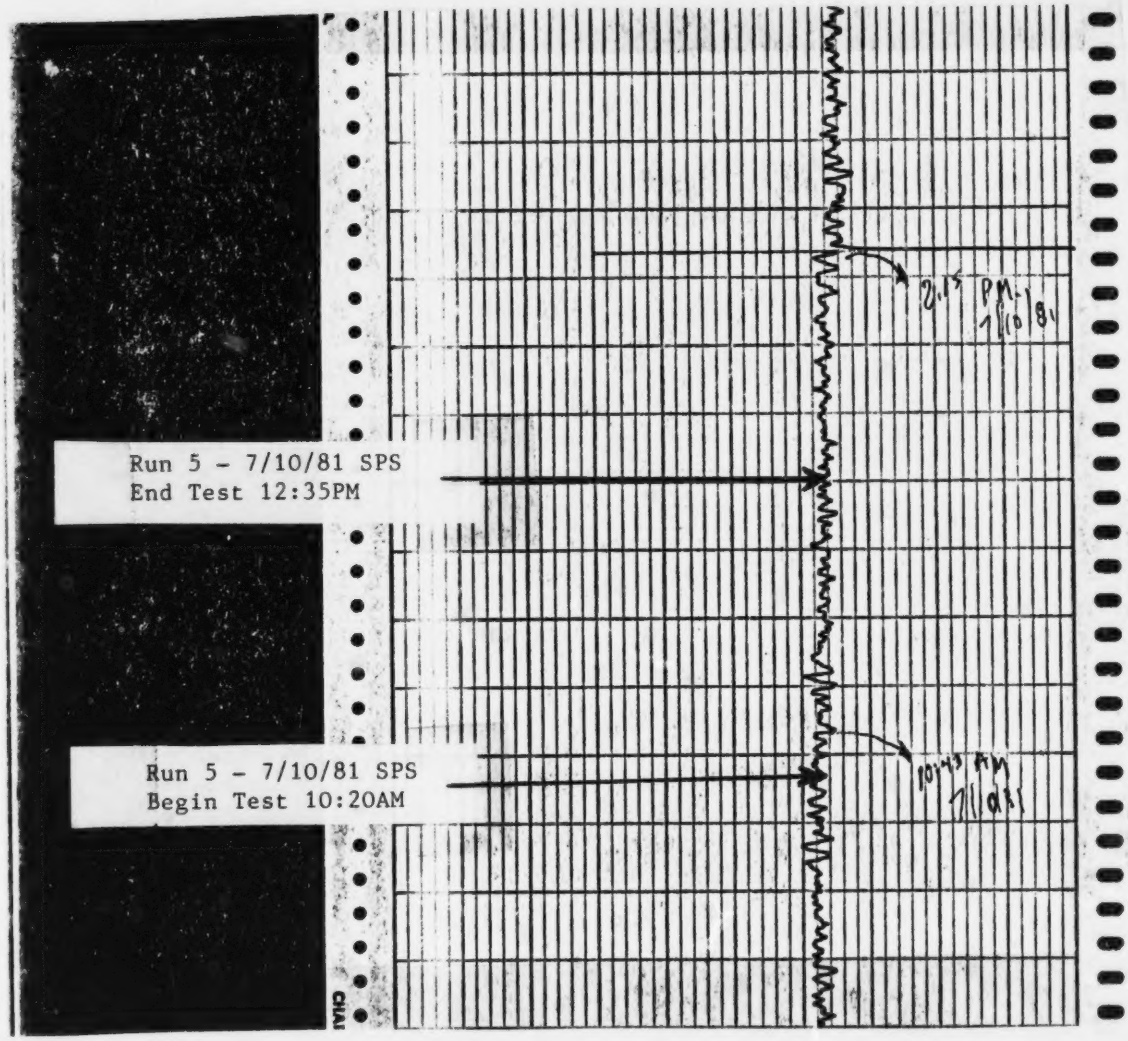
Oxygen - % - Range 3-5%
Divide Large Divisions
By 2 to get % O_2

Run 2 - 7/9/81 SPS
End Test 12:05PM

Run 2 - 7/9/81 SPS
Begin Test 9:30AM

9:31 AM
TEST
7/9/81


PRINTED IN U.S.A.
Run 4 - 7/9/81 SPS
End Test 10:50PM
JUL 10 1981
11 03 PM
Run 4 - 7/9/81 SPS
Begin Test 9:50PM
10 03 PM
7/9/81

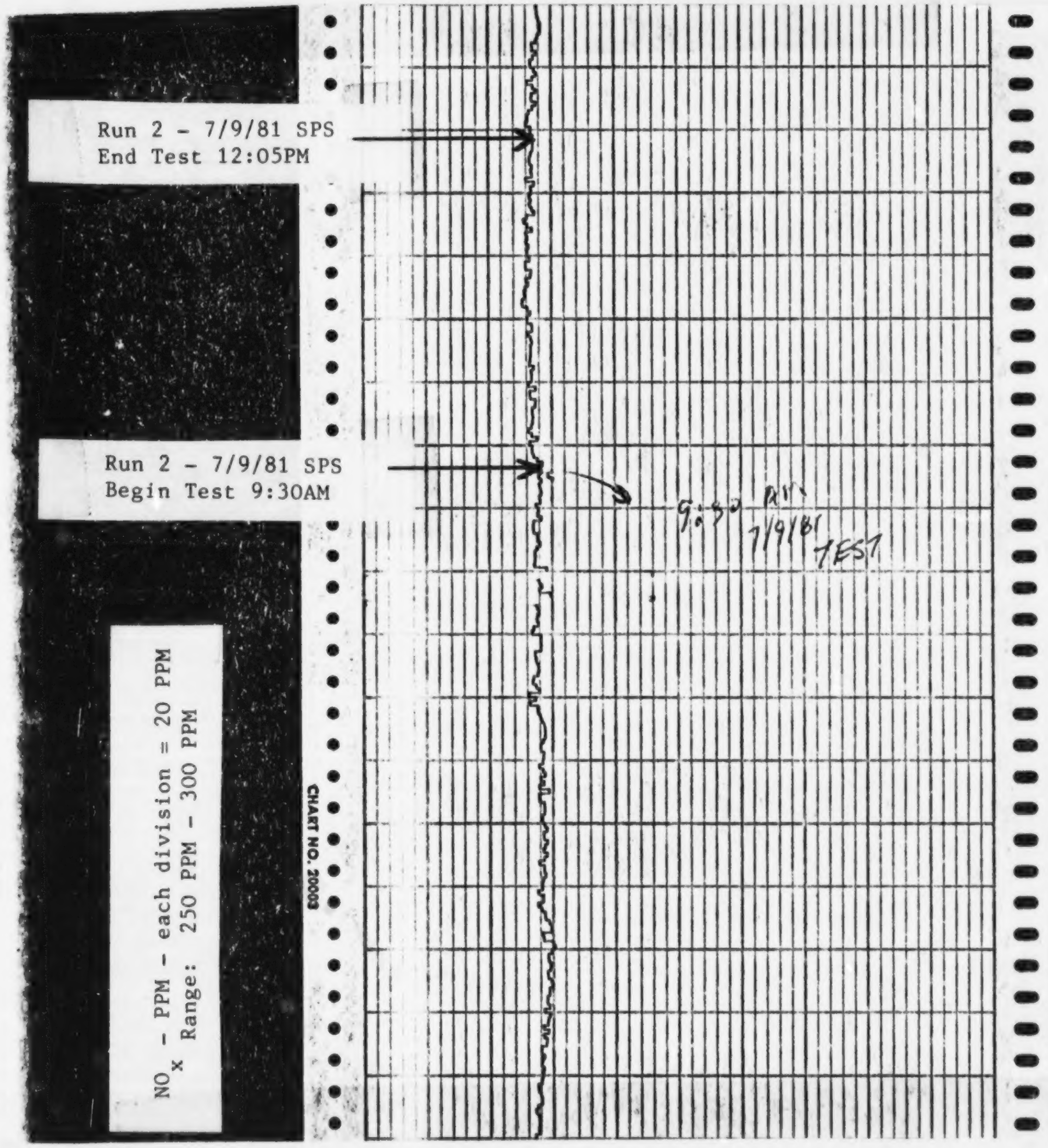


2:15 PM
7/10/81

Run 5 - 7/10/81 SPS
End Test 12:35PM

10:45 AM
7/10/81

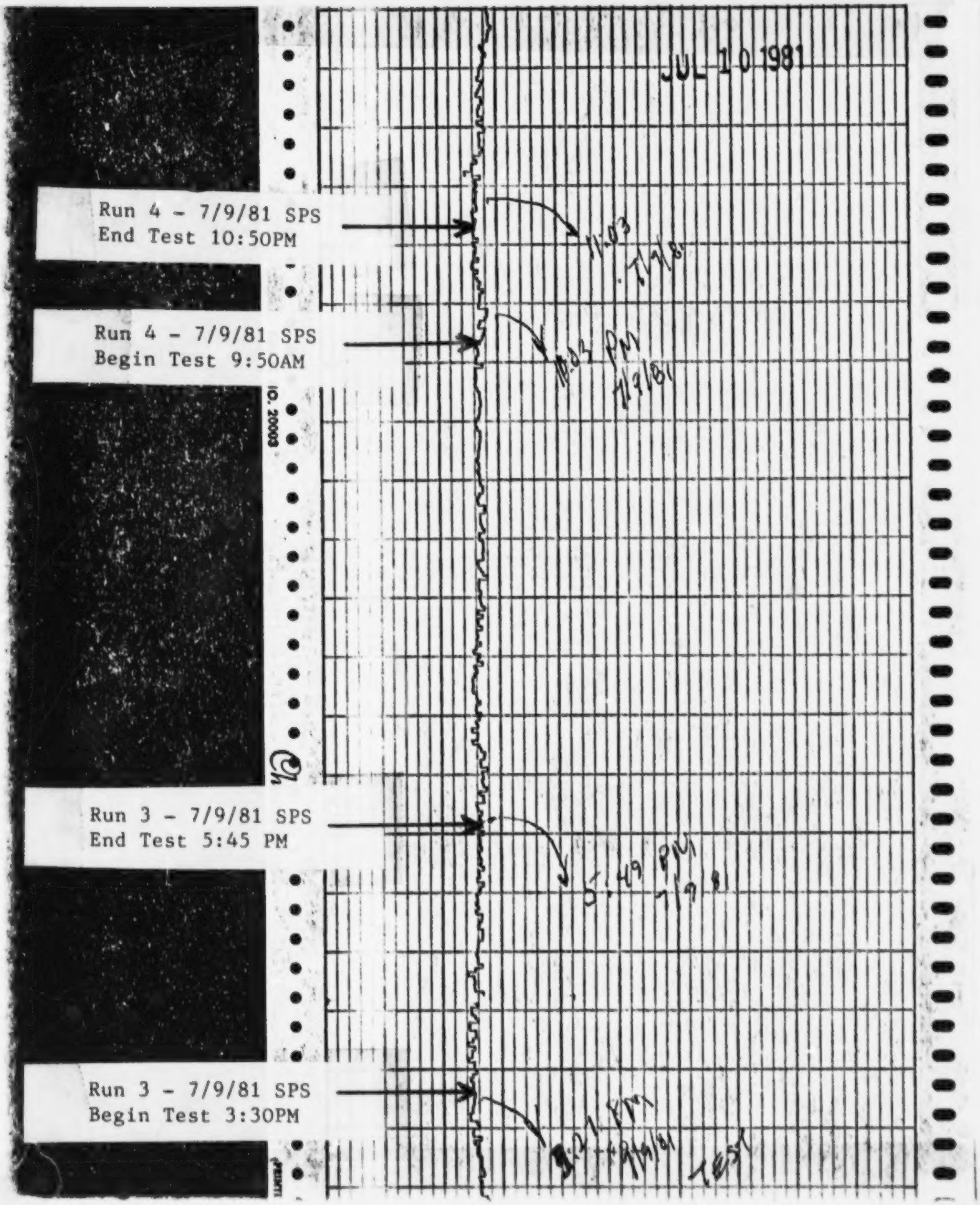
Run 5 - 7/10/81 SPS
Begin Test 10:20AM


Run 2 - 7/9/81 SPS
End Test 12:05PM

Run 2 - 7/9/81 SPS
Begin Test 9:30AM

9:30 am
7/9/81
TEST

NO_x - PPM - each division = 20 PPM
Range: 250 PPM - 300 PPM



JUL 10 1981

Run 4 - 7/9/81 SPS
End Test 10:50PM

11:03
7/9/81

Run 4 - 7/9/81 SPS
Begin Test 9:50AM

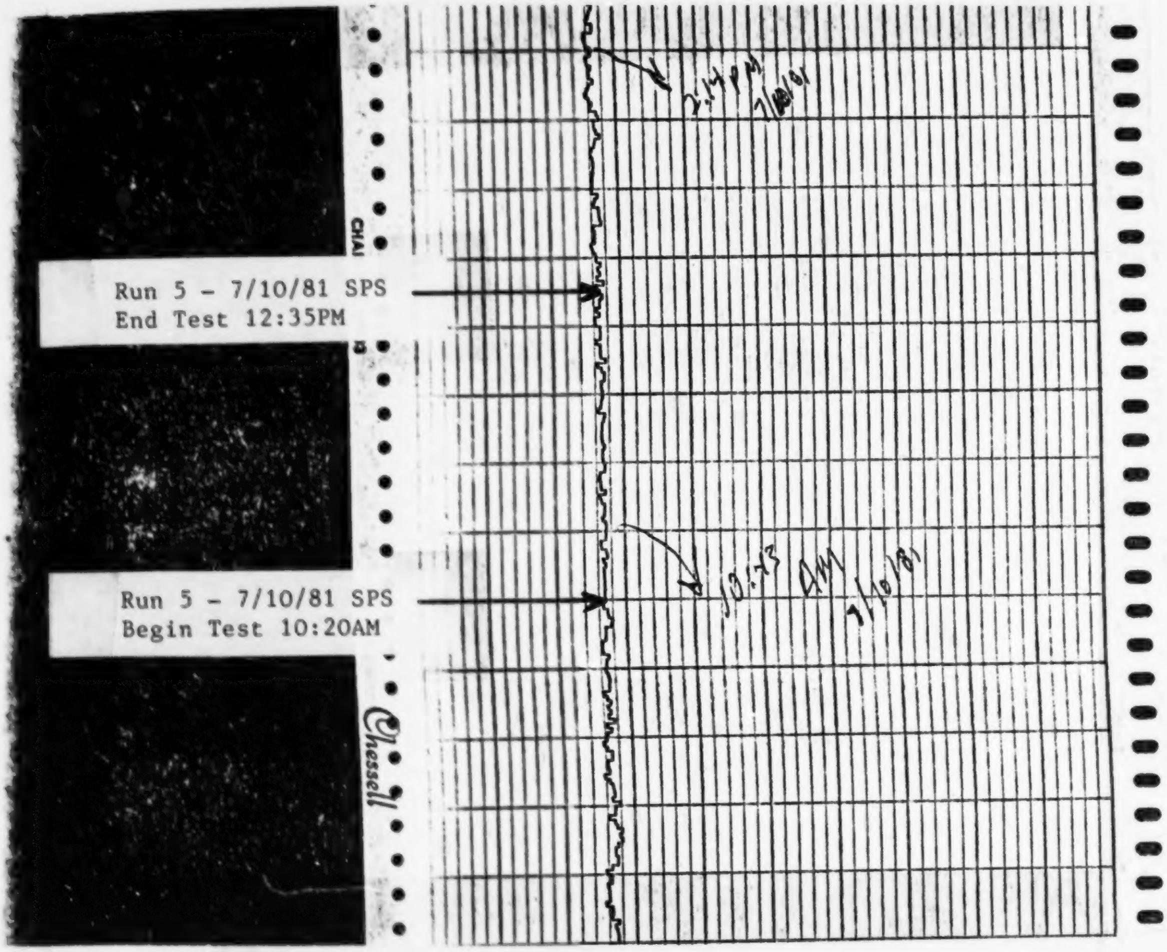
10:03 PM
7/9/81

Run 3 - 7/9/81 SPS
End Test 5:45 PM

5:49 PM
7/9/81

Run 3 - 7/9/81 SPS
Begin Test 3:30PM

[illegible]:21 PM
7/9/81
TEST

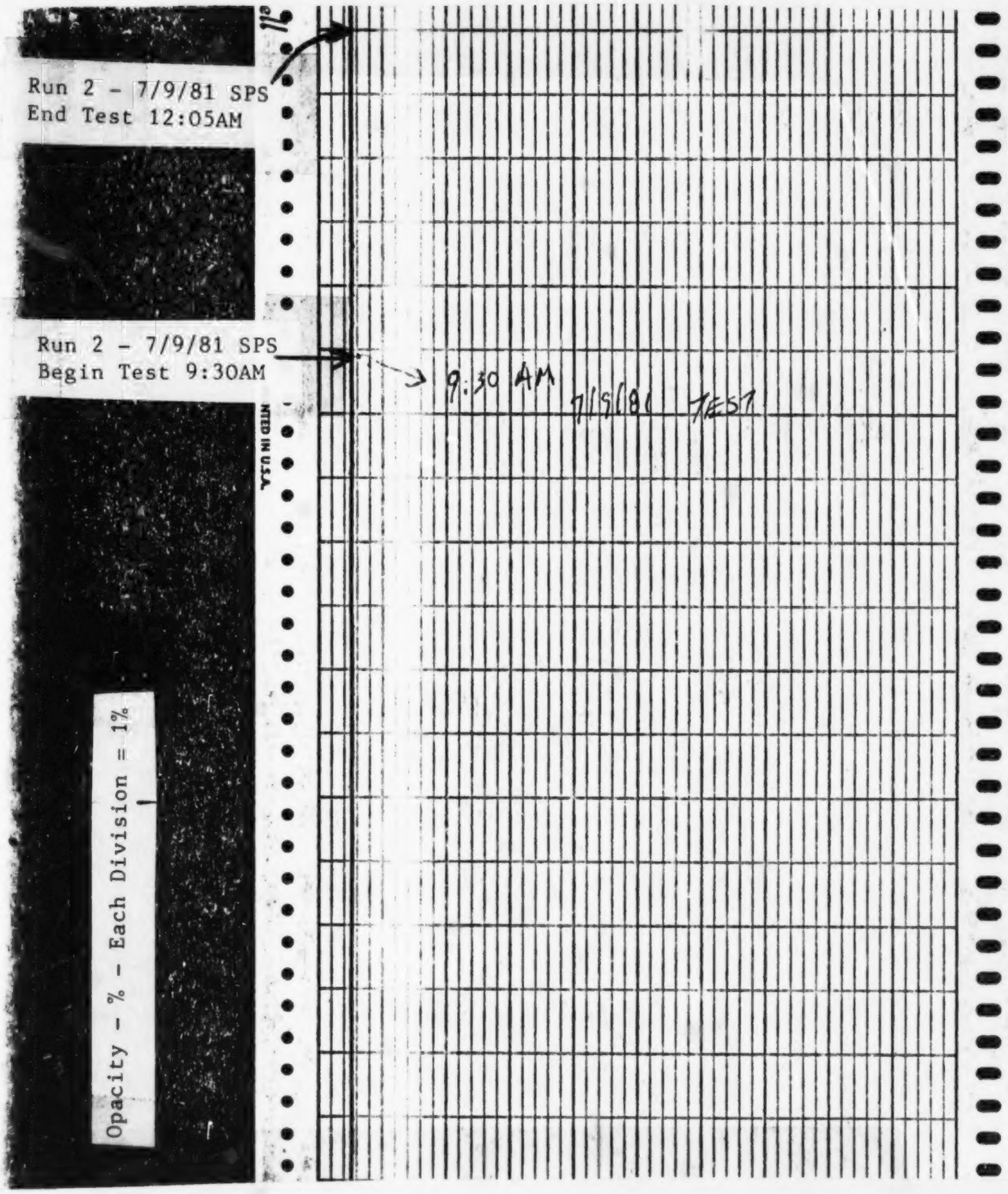


Run 5 - 7/10/81 SPS
End Test 12:35PM

Run 5 - 7/10/81 SPS
Begin Test 10:20AM

2:14 PM 7/[illegible]/81

10:23 AM 7/10/81

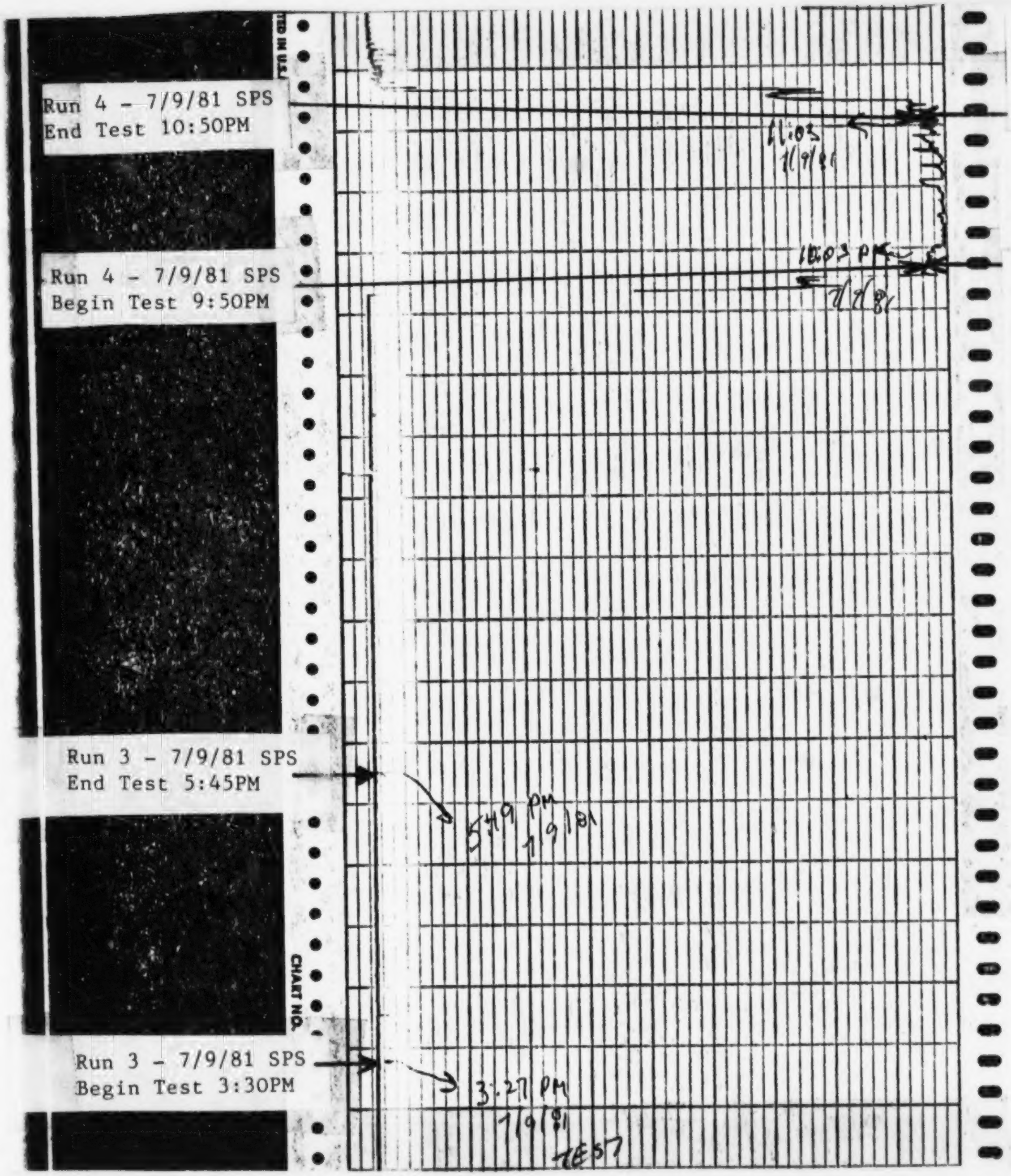


Run 2 - 7/9/81 SPS
End Test 12:05AM

Run 2 - 7/9/81 SPS
Begin Test 9:30AM

9:30 AM 7/9/81 TEST

Opacity - % - Each Division = 1%



Run 4 - 7/9/81 SPS
End Test 10:50PM

11:03
7/9/81

Run 4 - 7/9/81 SPS
Begin Test 9:50PM

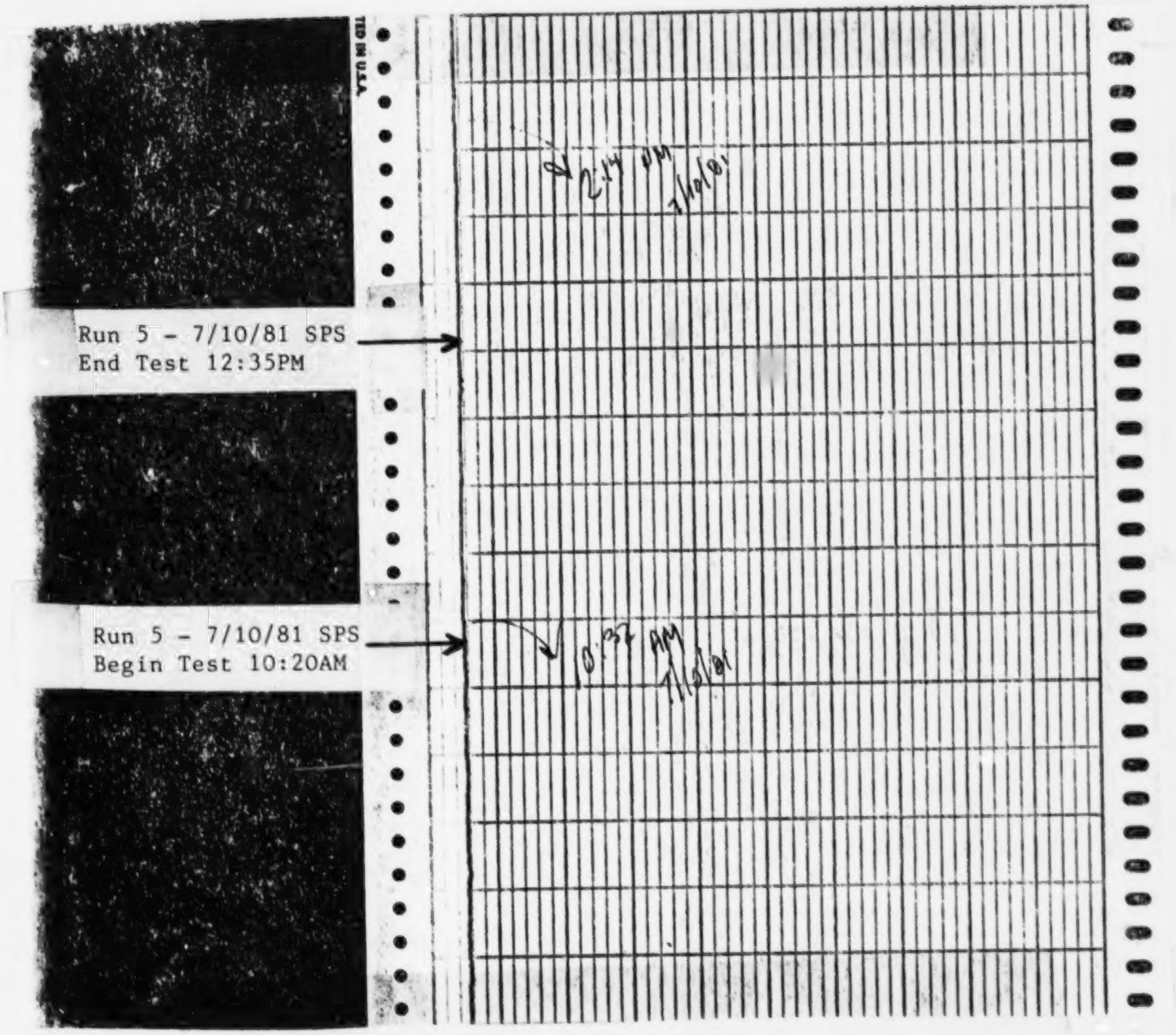
10:03 PM
7/9/81

Run 3 - 7/9/81 SPS
End Test 5:45PM

5:49 PM
7/9/81

Run 3 - 7/9/81 SPS
Begin Test 3:30PM

3:27 PM
7/9/81
TEST

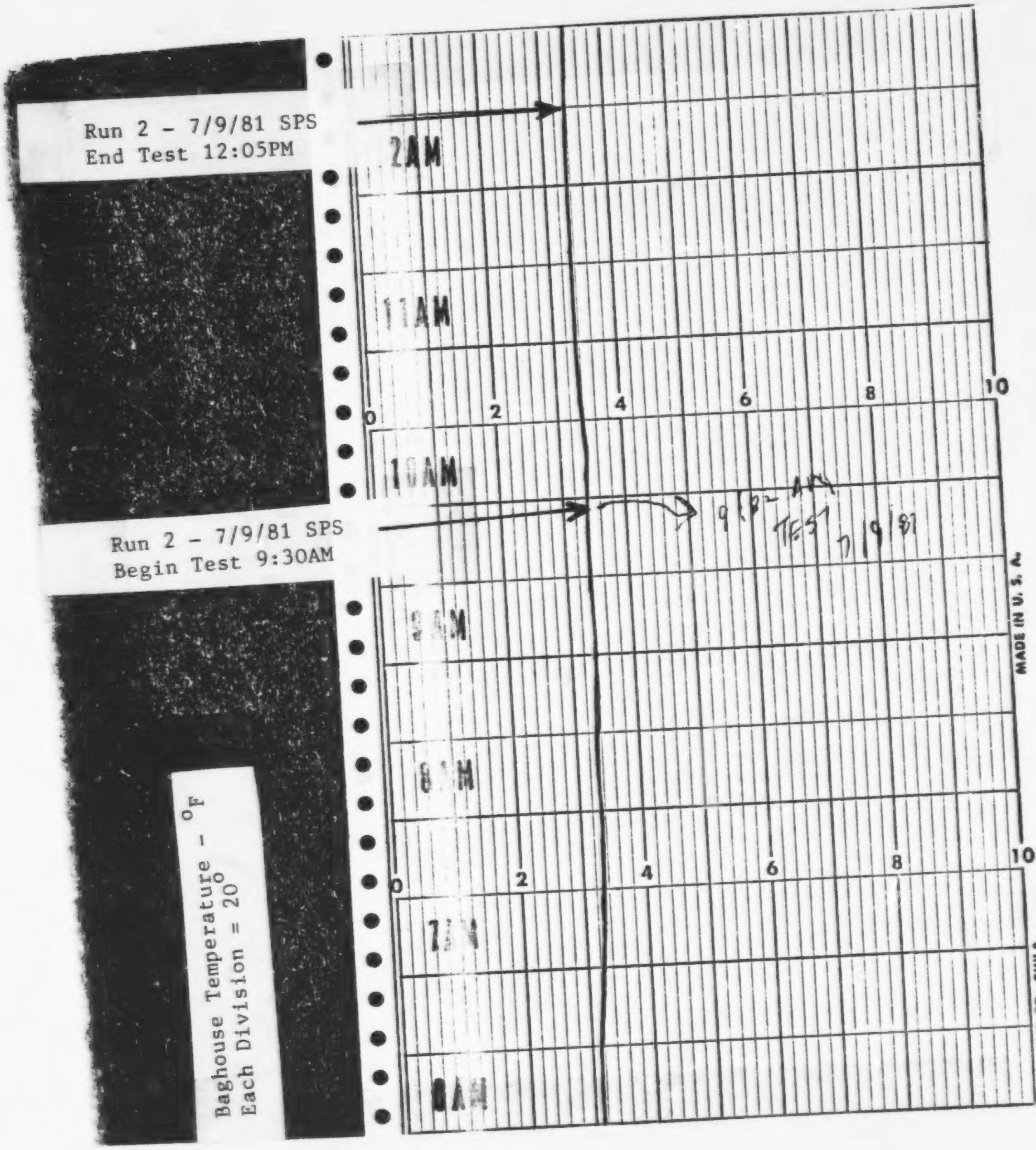


Run 5 - 7/10/81 SPS
End Test 12:35PM

2:14 PM
7/10/81

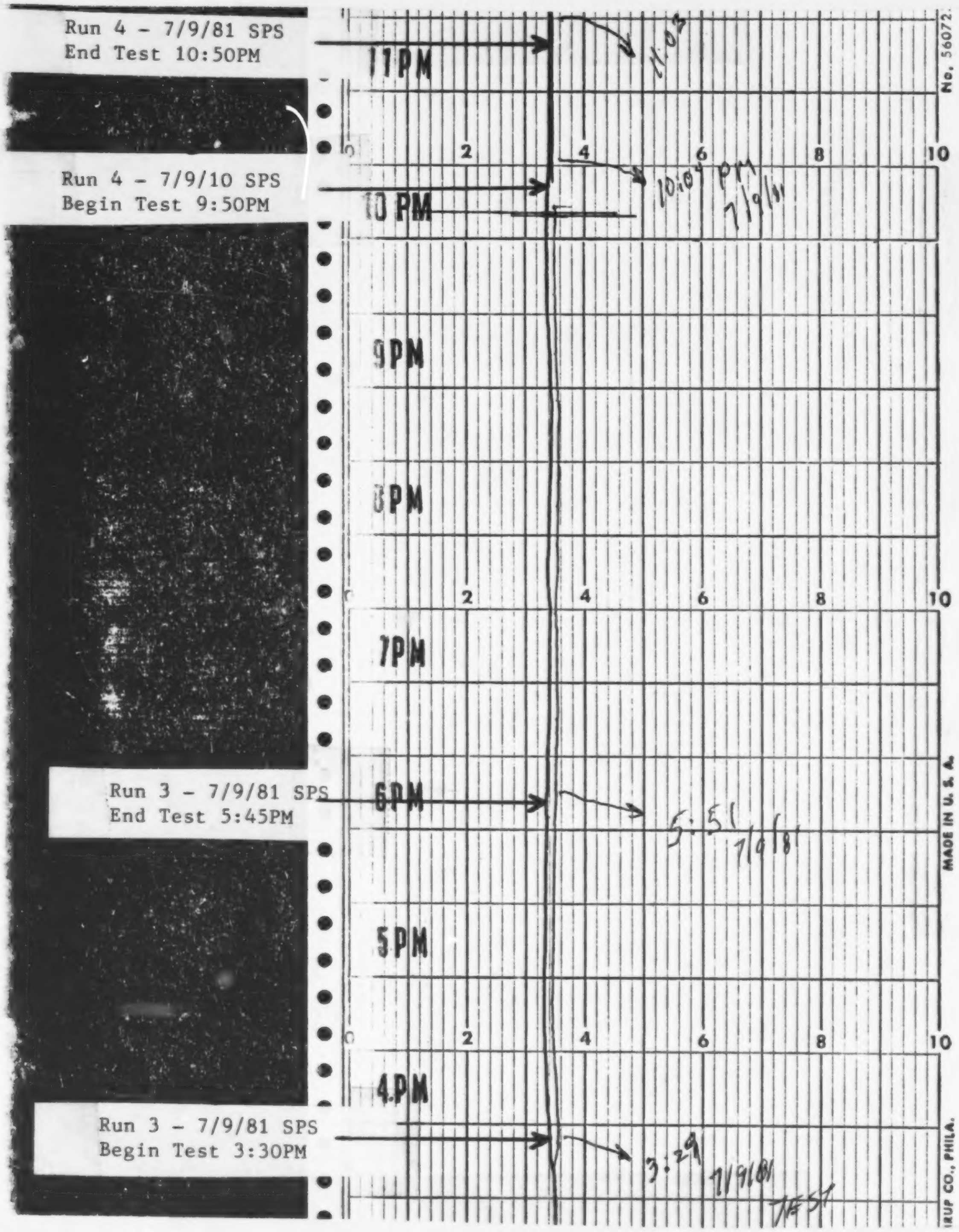
Run 5 - 7/10/81 SPS
Begin Test 10:20AM

10:37 AM
7/10/81


Run 2 - 7/9/81 SPS
End Test 12:05PM

Run 2 - 7/9/81 SPS
Begin Test 9:30AM

Baghouse Temperature - °F
Each Division = 20°

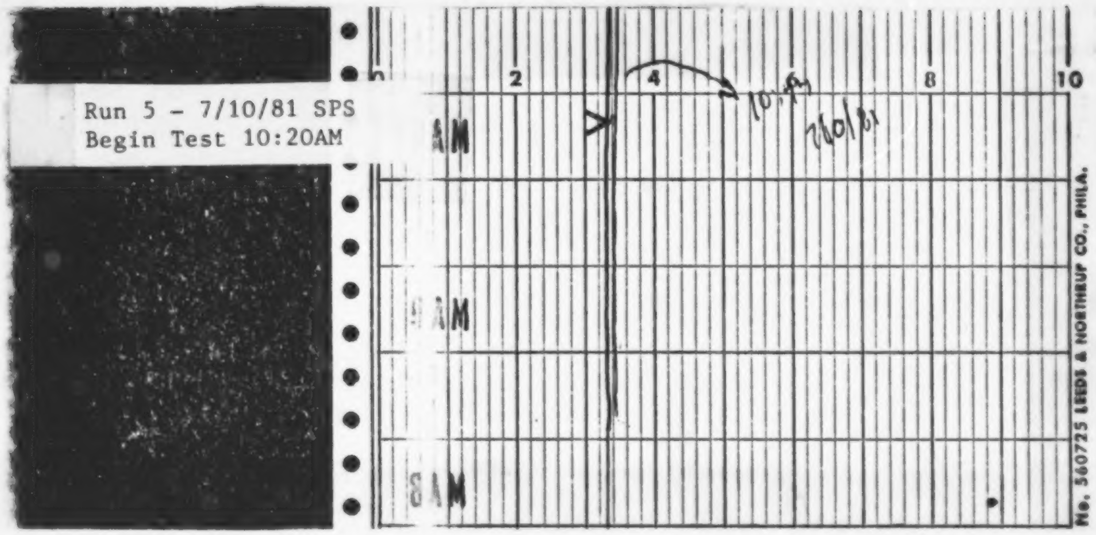


Run 4 - 7/9/81 SPS
End Test 10:50PM

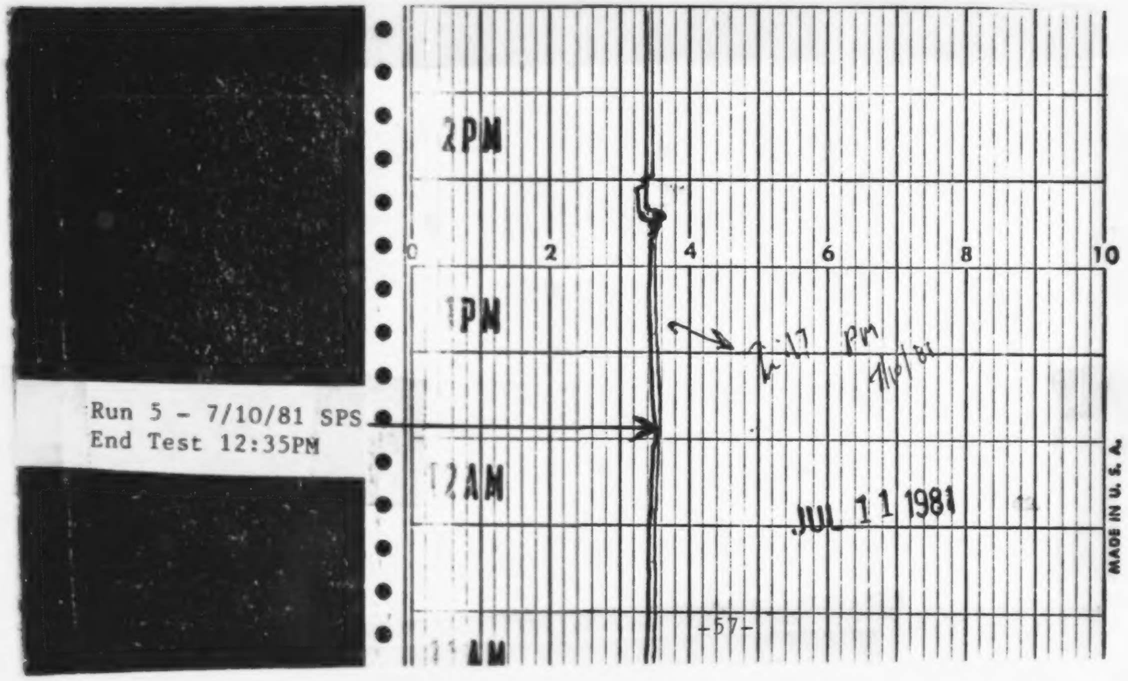
Run 4 - 7/9/10 SPS
Begin Test 9:50PM

Run 3 - 7/9/81 SPS
End Test 5:45PM

Run 3 - 7/9/81 SPS
Begin Test 3:30PM



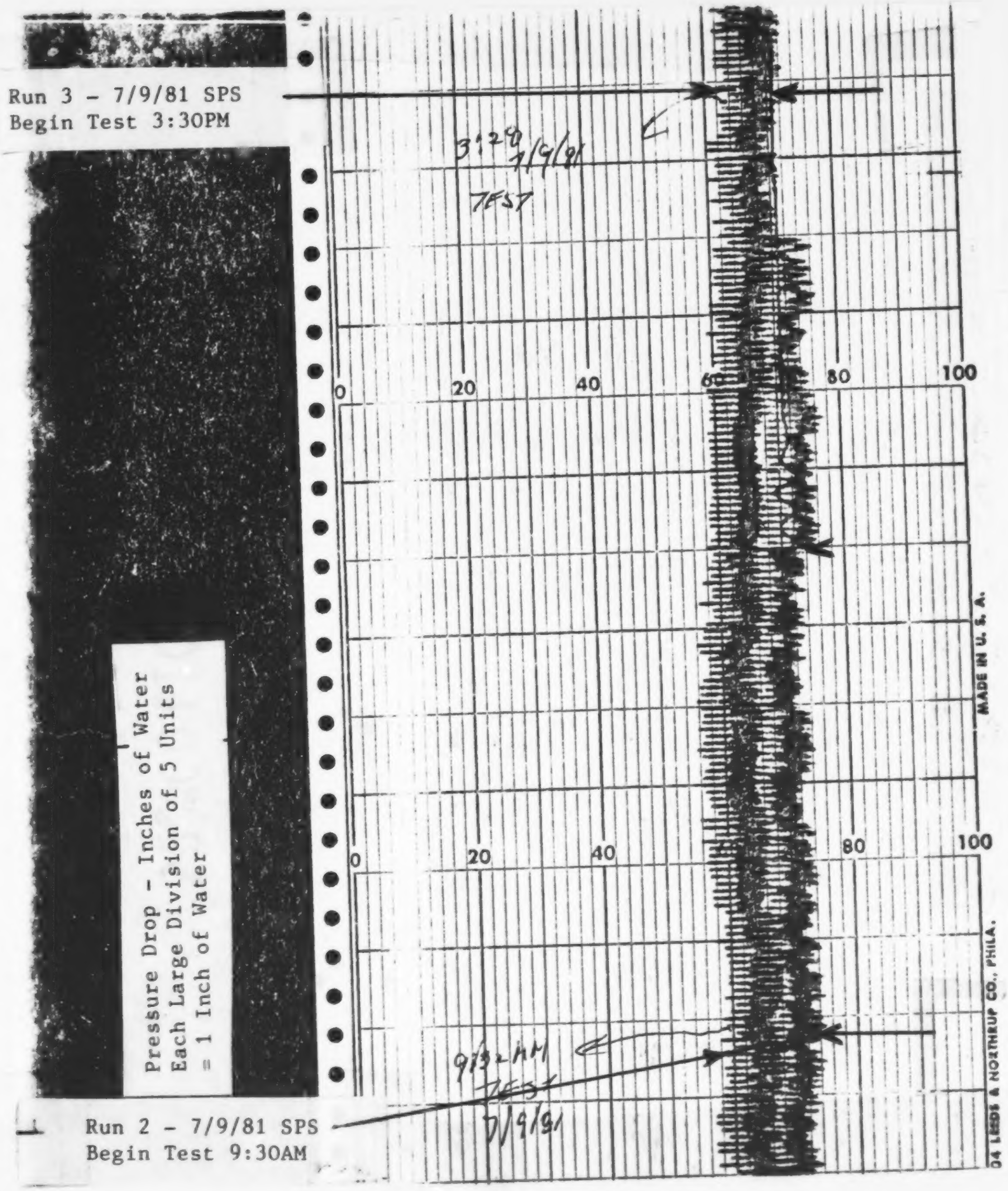
Run 5 - 7/10/81 SPS
Begin Test 10:20AM



Run 5 - 7/10/81 SPS
End Test 12:35PM

2:17 PM 7/10/81

JUL 11 1981



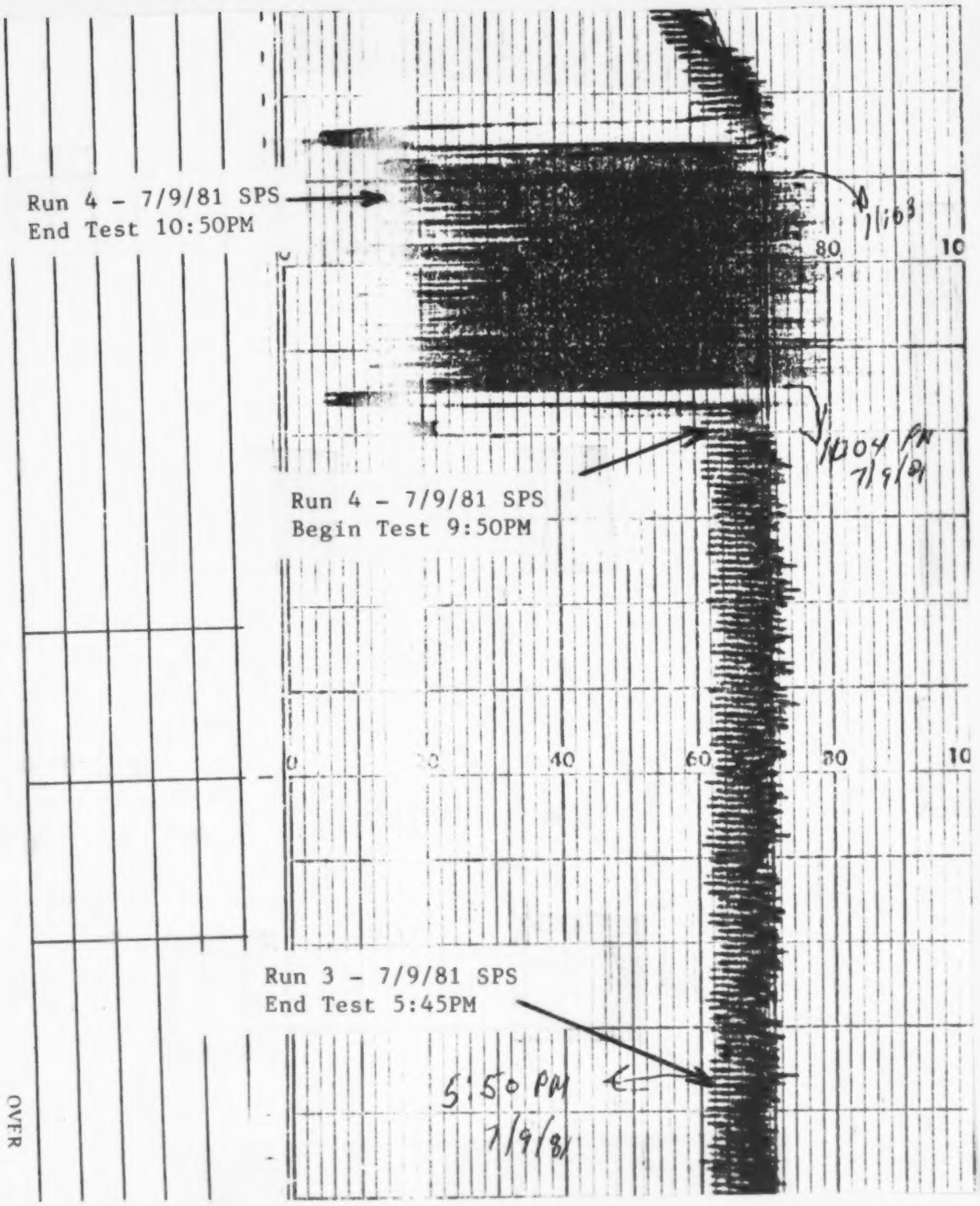
Run 3 - 7/9/81 SPS
Begin Test 3:30PM

3:20
7/9/81
TEST

Pressure Drop - Inches of Water
Each Large Division of 5 Units
= 1 Inch of Water

9:32 AM
TEST
7/9/81

Run 2 - 7/9/81 SPS
Begin Test 9:30AM



Run 4 - 7/9/81 SPS
End Test 10:50PM

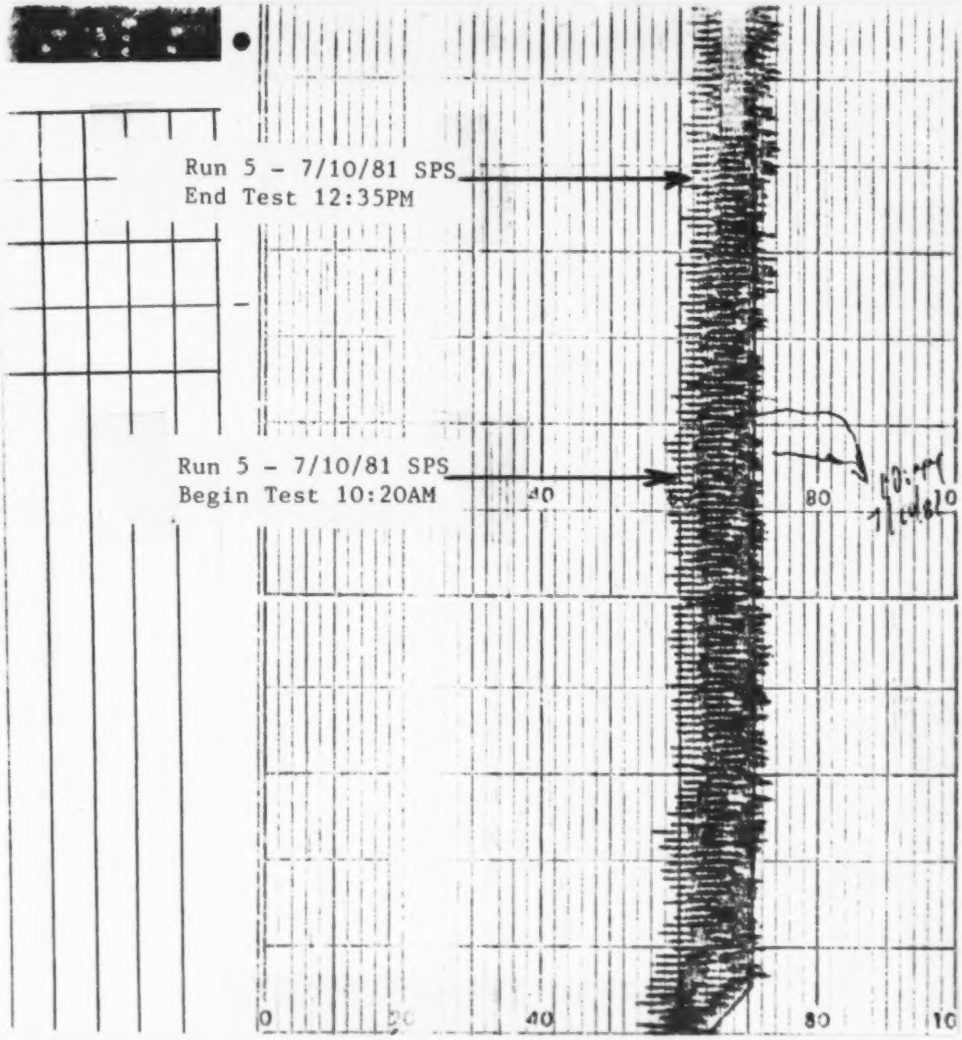
11:03

Run 4 - 7/9/81 SPS
Begin Test 9:50PM

1004 PM
7/9/81

Run 3 - 7/9/81 SPS
End Test 5:45PM

5:50 PM
7/9/81



Run 5 - 7/10/81 SPS
End Test 12:35PM

Run 5 - 7/10/81 SPS
Begin Test 10:20AM

10:20
7/10/81

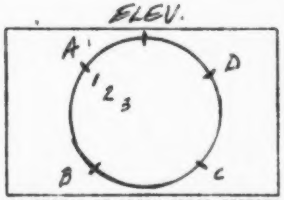
APPENDIX 4

Field Data Sheets

ENVIRONMENTAL TESTING SERVICES, INC.
ROANOKE, VA

A/C = 3:1
FILTER # GF5 331
THIMBLE #

PLANT SPS Har. STA.
LOCATION UNIT 3 OUTLET
OPERATOR DELANEY
DATE 7-9-81
RUN NO. 2
SAMPLE BOX NO. —
METER BOX NO. NUTECH #2
METER △ H@ 1.68
C FACTOR .96
PITOT TUBE COEFFICIENT, C_p .85



SCHEMATIC OF STACK CROSS SECTION

AMBIENT TEMPERATURE 62 °F
BAROMETRIC PRESSURE 27.20 " Hg
ASSUMED MOISTURE,% 5 %
PROBE LENGTH, m(ft) 13 FT.
NOZZLE IDENTIFICATION NO. 206
AVERAGE CALIBRATED NOZZLE DIAMETER,cm(in) .202
PROBE HEATER SETTING
LEAK RATE, m³/min(cfm) < .02 CFM
PROBE LINER MATERIAL 316 SS

TRAVERSE POINT NUMBER (TPN)	DIS-TANCE In.	CLOCK TIME	SAMPLING TIME (θ). min.	STATIC PRESSURE In. H_2O	VACUUM METER In. Hg	STACK TEMPERATURE (T_s) °C (°F)	VELOCITY HEAD (ΔP_s) mm(in.)H_2O	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER mm H_2O (in. H_2O)	GAS SAMPLE VOLUME m³ (ft³)	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET °C (°F)	GAS SAMPLE TEMPERATURE AT DRY GAS METER OUTLET °C (°F)	FILTER HOLDER TEMPERATURE °C (°F)	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °C (°F)
A 3	119.2	0930	0	.74	2	320	1.5	1.7	636.989		72°	235°	64°
2	81.8		10		2	318	1.5	1.7	644.5		78°		
1	56.3		20		2	330	1.1	1.3	652.2		82°		
B 3	119.2	1015	30	.85	2	310	1.6	2.0	659.072		80°		
2	81.8		40		2	320	1.7	1.9	667.3		82°		
1	56.3		50		2	315	1.2	1.4	675.5		84°		
C 3	119.2	1100	60	.79	2	322	1.7	1.9	682.616		84°	250°	78°
2	81.8		70		2	320	1.7	1.9	690.7		94°		
1	56.3		80		2	325	1.1	1.3	699.0		98°		
D 3	119.2	1135	90	.71	2	330	1.5	1.7	706.068		92°		
2	81.8		100		2	325	1.3	1.5	713.9		94°		
1	56.3		110		2	330	1.0	1.2	721.2		96°		
		1205	120						728.059				
TOTAL										Avg.	Avg.		
AVERAGE										Avg.			

Impinger Catch
#1 156 ml
#2 20 ml
#3 ml

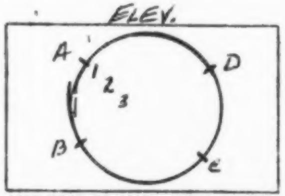
Orsat Analysis

CO_2	%	%	%	%
O_2	%	%	%	%
CO	%	%	%	%

ENVIRONMENTAL TESTING SERVICES, INC.
ROANOKE, VA

A/C = 3:1
FILTER # GFs 334
THIMBLE # ____

PLANT S/S HAR. STA.
LOCATION UNIT 3 OUTLET
OPERATOR DELANEY
DATE 7-9-81
RUN NO. 3
SAMPLE BOX NO. ____
METER BOX NO. NUTECH #2
METER △ H@ 1.68
C FACTOR .90
PITOT TUBE COEFFICIENT, C_p .85



SCHEMATIC OF STACK CROSS SECTION

AMBIENT TEMPERATURE 85°
BAROMETRIC PRESSURE 27.00" Hg
ASSUMED MOISTURE, % 10.0 %
PROBE LENGTH, m(ft) 13'
NOZZLE IDENTIFICATION NO. .206
AVERAGE CALIBRATED NOZZLE DIAMETER, cm(in) .202
PROBE HEATER SETTING ____
LEAK RATE, m^3/min(cfm) 2.02
PROBE LINER MATERIAL 316 SS

TRAVERSE POINT NUMBER (TPN)	DIS-TANCE In.	CLOCK TIME	SAMPLING TIME (Θ), min.	STATIC PRESSURE In. H_2O	VACUUM METER In. Hg	STACK TEMPERATURE (T_s) °C (°F)	VELOCITY HEAD (ΔP_s) mm(in.) H_2O	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER mm H_2O (in. H_2O)	GAS SAMPLE VOLUME, m^3 (ft^3)	GAS SAMPLE TEMPERATURE AT DRY GAS METER		FILTER HOLDER TEMPERATURE °C (°F)	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °C (°F)
										INLET °C (°F)	OUTLET °C (°F)		
D 3	119.2	1530	0		2	320	1.5	1.6	730.503		88°	250°	68
2	81.8		10		2	318	1.3	1.4	738.0		92°		
1	56.3		20		2	330	1.0	1.1	745.1		94°		
C 3	119.2		30		2	316	1.7	1.8	751.6		94°	260°	70
2	81.8		40		2	320	1.7	1.8	759.8		94°		
1	56.3		60		2	315	1.7	1.2	768.1		94°		
B 3	119.2		60		2	322	1.8	1.9	774.9		92°	260°	80
2	81.8		70		2	320	1.7	1.8	783.1		90°		
1	56.3		80		2	325	1.7	1.3	791.0		90°		
A 3	119.2		90		2	330	1.5	1.6	797.8		88°	265°	74
2	81.8		100		2	325	1.5	1.6	805.6		88°		
1	56.3		110		2	330	1.1	1.2	813.3		88°		
		1745	120						821.0				
TOTAL										Avg.	Avg.		
AVERAGE										Avg.			

Impinger Catch
#1 128 ml
#2 2 ml
#3 112 ml
33 gm.

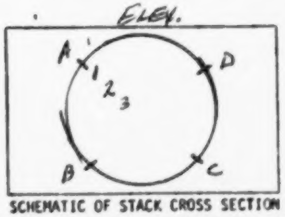
Orsat Analysis

CO_2	%	%	%	%
O_2	%	%	%	%
CO	%	%	%	%

ENVIRONMENTAL TESTING SERVICES, INC.
ROANOKE, VA

A/C = 3:1
FILTER # GFs 34
THIMBLE # T 211

PLANT SPS HAR. STA.
LOCATION UNIT 3 OUTLET
OPERATOR DELANEY
DATE 7-9-81
RUN NO. 4, INLET #1
SAMPLE BOX NO.
METER BOX NO. NUTECH #2
METER △ H@ 1.68
C FACTOR .90
PITOT TUBE COEFFICIENT, C_p .85



SCHEMATIC OF STACK CROSS SECTION

AMBIENT TEMPERATURE 75°F
BAROMETRIC PRESSURE 26.94 " Hg
ASSUMED MOISTURE,% 10 %
PROBE LENGTH, m(ft) 13'
NOZZLE IDENTIFICATION NO. .206
AVERAGE CALIBRATED NOZZLE DIAMETER,cm(in) .202

PROBE HEATER SETTING
LEAK RATE, m³/min(cfm) < .02 CFM
PROBE LINER MATERIAL 316 SS

TRAVERSE POINT NUMBER (TPN)	DIS-TANCE In.	CLOCK TIME	SAMPLING TIME (θ). min.	STATIC PRESSURE In. H_2O	VACUUM METER In. Hg	STACK TEMPERATURE (T_s) °C (°F)	VELOCITY HEAD (ΔP_s) mm(in.)H_2O	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER mm H_2O (in. H_2O)	GAS SAMPLE VOLUME m^3 (ft^3)	GAS SAMPLE TEMPERATURE AT DRY GAS METER		FILTER HOLDER TEMPERATURE °C (°F)	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °C (°F)
										INLET °C (°F)	OUTLET °C (°F)		
A 3	119.2	2150	0	.85	4	336	1.4	1.5	820.1		82	250	68
2	81.9		5		5	338	1.4	1.5	823.9		82		
1	56.3		10		5	336	1.05	1.15	827.3		82		
B 3	119.2		15		6	340	1.5	1.6	830.4		82	250	64
2	81.9		20		6	341	1.5	1.6	834.2		84		
1	56.3		25	.74	6	343	1.1	1.2	838.0		84		
C 3	119.2		30		7	343	1.7	1.8	841.3		84	260	62
2	81.8		35		7	344	1.6	1.7	845.2		84		
1	56.3		40		7	343	1.4	1.5	849.0		84		
D 3	119.2		45		8	342	1.7	1.8	852.8		84		68
2	81.9		50		8	343	1.6	1.7	856.6		84	260	
1	56.3		55		8	342	1.4	1.5	860.5		87		
			60						864.3				
TOTAL										Avg.	Avg.		
AVERAGE										Avg.			

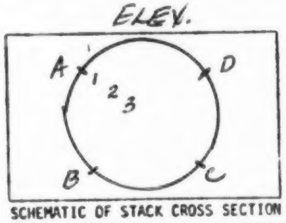
Impinger Catch
#1 ml
#2 ml
#3 ml

Orsat Analysis
CO_2 % % % %
O_2 % % % %
CO % % % %

ENVIRONMENTAL TESTING SERVICES, INC.
ROANOKE, VA

A/C = 3:1
FILTER # GF5 330
THIMBLE #

PLANT SPS HAR. STA.
LOCATION UNIT 3 OUTLET
OPERATOR DELANEY
DATE 7-10-81
RUN NO. 5 #4 OUTLET
SAMPLE BOX NO.
METER BOX NO. NUTECH #2
METER △ H@ 1.68
C FACTOR .90
PITOT TUBE COEFFICIENT, C_p .85



SCHEMATIC OF STACK CROSS SECTION

AMBIENT TEMPERATURE 75°
BAROMETRIC PRESSURE 26.98
ASSUMED MOISTURE,% 10 %
PROBE LENGTH, m(ft) 13'
NOZZLE IDENTIFICATION NO. 206
AVERAGE CALIBRATED NOZZLE DIAMETER, cm(in) .202
PROBE HEATER SETTING
LEAK RATE, m^3/min(cfm) ≤ .02 CFM
PROBE LINER MATERIAL .316 SS

TRAVERSE POINT NUMBER (TPN)		DIS-TANCE In.	CLOCK TIME	SAMPLING TIME (θ). min.	STATIC PRESSURE In. H_2O	VACUUM METER In. Hg	STACK TEMPERATURE (T_s) °C (°F)	VELOCITY HEAD ($\triangle P_s$) mm(in.)H_2O	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER mm H_2O (in. H_2O)	GAS SAMPLE VOLUME m^3 (ft^3)	GAS SAMPLE TEMPERATURE AT DRY GAS METER		FILTER HOLDER TEMPERATURE °C (°F)	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °C (°F)
											INLET °C (°F)	OUTLET °C (°F)		
B	3	119.2	1020	0	.42	3	333	1.6	1.7	864.3		91°	260	68°
	2	81.8		10		3	334	1.6	1.7	872.1		94°		
	1	56.3		20		3	335	1.2	1.3	879.9		96°		
C	3	119.2		30	.88	3	325	1.7	1.8	886.8		94°	265	72°
	2	81.8		40		3	324	1.6	1.7	894.9		93°		
	1	56.3		50		3	321	1.2	1.3	902.8		96°		
D	3	119.3		60	.40	3	318	1.4	1.5	909.8		94°	265	70°
	2	119.3		70		3	318	1.4	1.5	917.2		95°		
	1	81.8		80		3	322	1.4	1.5	924.6		94°		
A	3	81.8		90		3	322	1.4	1.5	932.0		94°	265	70°
	2	56.3		100		3	312	1.1	1.2	939.4		95°		
	1	56.3		110		3	315	1.1	1.2	946.0		95°		
			1235	120						952.7				
TOTAL											Avg.	Avg.		
AVERAGE											Avg.			

Impinger Catch
#1 142 ml
#2 18 ml
#3 2 ml

Orsat Analysis
CO_2 ____ % ____ % ____ % ____ %
O_2 ____ % ____ % ____ % ____ %
CO ____ % ____ % ____ % ____ %

APPENDIX 5

Cascade Impactor Test Results

CASCADE IMPACTOR SAMPLING
AT A FABRIC FILTER BAGHOUSE

by

C. A. Pareja, A. D. Shendrikar, and D. S. Ensor

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Research Triangle Park, North Carolina 27709

Submitted to

ETS, Inc.
3140 Chaparral Drive, S. W.
Roanoke, Virginia 24018

October 1981

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SECTION 1

INTRODUCTION

In support of U. S. Environmental Protection Agency project work, impactor tests were carried out during the week of July 6-10, 1981, at Harrington Station operated by the Southwestern Public Service Company (SWPS) in Amarillo, Texas. Inlet and outlet of Baghouse Unit No. 3 were tested to measure size segregated particulate emissions using MRI inertial cascade impactors. Because of the lack of inlet port, one sample was collected when stack gases were bypassing the baghouse to simulate inlet conditions. Three outlet samples were obtained during the testing period of July 6-10, 1981.

SECTION 2

SUMMARY AND CONCLUSIONS

1. The impactor sampling was successfully conducted with three tests at the stack with the baghouse operating normally and one test with the baghouse compartments bypassed.

2. All outlet tests including a blank showed sample weight losses in spite of extended sampling times. The weight losses which could be due to either weighing problems or loss of the grease was exacerbated by the low concentration of particulate matter in the outlet flue gas.

   The balance was damaged slightly during transport to the site; consequently, the span could not be adjusted to match the 100 mg calibration weight. (The balance was adjusted to 107, the limit of the calibration screw.) However, the balance was demonstrated, by the use of calibration weights, to have satisfactory performance during the test.

   The weight losses on the substrates were believed to be due to chemical reactions of the flue gas with the grease to form volatile materials. The Harrington flue gas must have some unusual trace reactive gases because the Apiezon-H grease has performed satisfactorily at other test sites.

3. All of the outlet size distribution data were adjusted using the blank test substrate weight losses. This approach was based on the following assumptions:

   a. The weight loss was linear with time. In other words, the longer the substrate was exposed to the flue gas, the more grease would be lost from the substrate.

   b. The weight losses were unique for each stage in the impactor because each stage has a different hole diameter and jet velocity.

It is recognized that the weight corrections are arbitrary, and other approaches could be used. For this reason, all the corrections are described in this report.

4. With the corrections, the results are fairly consistent between runs and with other measurements of size distribution. The mass mean diameter varied from 7.5 to 13 μm for the three tests.

   The shapes of the size distribution and penetration curves seem reasonable. However, the magnitude of the distribution is strongly affected by the substrate weight loss corrections.

5. The survey nature of the particle sizing at the Harrington Station dictated a rather limited effort in impactor testing. As a result, substrates (Apiezon-H on stainless steel) were selected which would provide the best results based on experience at other power plants. However, it was not until the test was conducted that the inadequacy of the grease was discovered.

   In future tests at the Harrington Station, a pretest visit should consist of the evaluation of a number of substrates to select the best substrate before the actual test.

SECTION 3

IMPACTOR SAMPLING

Impactor sampling provides a size segregated sample of particulate matter contained in the flue gas. MRI inertial cascade impactors were used to aerodynamically size the particles nominally in the diameter range of 0.5 to 10 µm. The impactor design (see Figure 1) is based on a simple annular arrangement of round jets[1] placed in a circular pattern impinging on annular collectors. There are seven impaction stages followed by a final filter. The use of collection discs permits flexibility in choice of substrate. For example, either a grease or a filter mat can be used to enhance sample collection and its retention on the substrate.

At the Harrington Station, stainless steel discs coated with Apiezon-H grease were used to collect fine particle samples from the stack gases. The collection discs have relatively low tare weights and, thus, are ideal for particle sizing sampling since small weight gains due to sample mass can be accurately weighed. Before sampling, impactor collection discs were prepared at the RTI chemistry laboratory. The presampling preparations included individual disc cleaning with 6N hydrochloric acid and rinsing several times in distilled water, followed by a thorough acetone wash. The discs were allowed to dry and coated using a solution of Apeizon-H grease in toluene (1/2 in. length of grease from the tube in 50 ml toluene). The discs were then placed in a tray and heated in an oven at 300° F for 4 hours. At the end of this period, the discs were removed, cooled, placed in petri dishes, and desiccated for at least 12 hours before presampling weighing. All the substrates were also rebaked in the field in an oven at stack temperature (350° F). The backup filter (Reeve Angel 934AH) was conditioned with stack gases for 6 hours at the Waynesboro facility, desiccated for 12 hours, and weighed before loading it in the impactor.

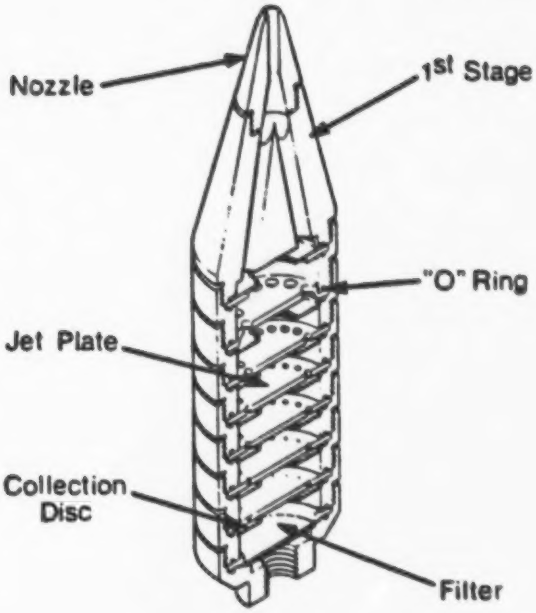

Figure 1. MRI cascade impactor.

Typically, the sampling train consisted of an impactor attached to a probe, followed by a series of impingers placed in an ice bath. The first two impingers each contained 250 ml of distilled water. The third impinger was empty and collected carry-over flue gas condensables from the first two impingers. The fourth impinger had a known weight of silica (approximately 300 g) used for removing the remaining moisture from the gases. The other sampling accessories included pressure and temperature read-outs, a vacuum pump, and a dry gas meter to measure the volume sampled.

The impactor samples were collected by following a procedure similar to that described by Harris.[2] There was a large concentration difference between inlet and outlet conditions. The outlet impactor tests were conducted up to 15 hours to obtain enough sample mass to weigh. The inlet tests of uncontrolled flue gas were run for only 1 minute, and a comparatively smaller flow rate (0.273 acfm) was used to obtain adequate size sample without overloading the impactor stages. During the test period, one inlet and three outlet samples were collected. All samples were collected at a single point inside the stack.

After the sampling, the impactor was removed from the duct, detached from the probe, and allowed to cool. All samples were recovered inside a work trailer. The impactor was carefully disassembled and collection discs were placed into petri dishes for protection and storage. Sample material collected on the inside walls of the impactor were brushed onto the appropriate collection stages. Samples were desiccated at least 24 hours before determining weight gains using a Perkin-Elmer AD-2Z autobalance.

A computer program developed by Denver Research Institute and modified by RTI was used to reduce the size distribution data and generate plots of differential mass distributions and penetrations. Individual data points are not shown since plots show the derivative of an interpolated cumulative size distribution and not the raw data. Particle size distributions are presented as a function of inertial aerodynamic diameter. The particulate collection efficiency of the baghouse is computed by comparison of simultaneous tests at the inlet and outlet. The calculation is made for both total particulate mass and as a function of particle size; the results are expressed as percent penetration. The density of particulate matter was assumed to be 2.4 g/cm^3, a typical value for fly ash. The other parameters needed for impactor data reduction were as follows: water vapor, 4.23 percent; CO_2, 12.13 percent; O_2, 5.60 percent; CO, 0.1 percent; and nitrogen, 80.0 percent.

SECTION 4

RESULTS AND DISCUSSION

The impactor tests conducted and the mass loadings obtained are listed in Table 1. During the week of July 6-10, 1981, samples from one blank run, one inlet run, and three outlet runs were collected. Concurrent inlet and outlet impactor samplings could not be performed because inlet ports were not installed. Consequently, the one 1-minute inlet sample was collected when stack gases were bypassing the Unit No. 3 baghouses. This test with the other outlet tests has been used to calculate the baghouse mass efficiencies and penetration.

Substrate weighings on July 7, 1981, from a blank run with filtered stack gas indicated that each of the impactor substrates had lost weight after 2 hours of sampling. The weight losses are tabulated in Table 2 and may have occurred because of:

- Weighing problems--function of balance performance as experienced during calibration and/or repetitive weighings of the "control" substrate several times a day for four consecutive days.
- Evaporation of Apiezon-H grease from the substrates due to the high stack temperature (over 340° F).
- Instability of Apiezon-H grease as reactions between stack components and grease may have resulted in product(s) that vaporize at stack temperatures.

In terms of balance performance, the 100 mg class "M" weight could be adjusted to read initially to 130 mg and subsequently to 107 mg. This was considered to be a minor problem since this positive bias remained consistent (see Table 3) throughout all weighing operations during the field testing week. Consequently, the balance calibration was checked each time before, during, and after weighing of the substrates. Simultaneous attempts were also made to evaluate the balance performance in terms of its ability to

Table 1. Summary of Impactor[a] Tests at Harrington Station

Sampling date	Test run number	Port number	Sampling time	Sampling rate (acfm)	gr/ft^3[b]		Percent efficiency[c]	Percent penetration[c]
					Inlet	Outlet		
7/7/81	1	A	2 hrs	0.42		blank run		
7/8/81	2	A	3 hrs	0.547		0.0004	99.96	0.04
7/8/81	3	A	8 hrs	0.634		0.0007	99.93	0.07
7/9/81[d]	4	C	1 min	0.273	1.06			
7/10/81	5	A	13 hrs 51 min	0.549		0.0015	99.86	0.14

[a] The impactor was positioned about 6 ft from the inside wall of the stack.

[b] The mass concentrations reported are at normal temperature (20° C) and pressure (76 cm Hg).

[c] One inlet sample and three outlet samples were collected on three different sampling days. Therefore, one inlet value was used to calculate mass efficiency and penetration of the baghouse for three different sampling days.

[d] The baghouse was bypassed to simulate inlet conditions.

Table 2. Blank Impactor Run[a]

Impactor stage number	Tare weight (mg)	Final weight (mg)	Weight loss (mg)
A	116.05	115.68	-0.37
B	158.29	157.84	-0.45
C	144.47	144.29	-0.18
D	140.57	140.15	-0.42
E	92.57	92.02	-0.55
F	143.86	143.31	-0.55
G	141.95	141.49	-0.46
H (filter)	101.43	101.17	-0.26

[a] See Table 1 for sampling details.

Table 3. Precision of Weighings of "Control" Substrate*

Date	Time (hrs)	Calibration weight (mg)	Span (mg)	Control weight (mg)
7/7/81		100	130	84.88
7/7/81	1600	100	107	69.82
7/7/81	2115	100	107	69.87
7/8/81	0530	100	107	69.89
7/8/81	1730	100	107	69.74
7/8/81	1855	100	107	69.79
7/8/81	2145	100	107	69.79
7/9/81	0545	100	107	69.81
7/9/81	1500	100	107	69.83
7/10/81	1200	100	107	69.81

* The control substrate was kept in the desiccator between weighings and used only to check the balance.

reproduce the weight of a control substrate over a period of time. Data obtained (see Table 3) indicated a good weighing precision. Results included in Table 4 indicate that the positive 7 percent bias for 100 mg class "M" weight was also applicable to lower weights also. Therefore, it was concluded that if weighings are performed under identical calibrated conditions before and after sampling, the weighing operation should provide reasonably precise and accurate sample weights.

Based on this assumption, all impactor samples were weighed in the field before and after sampling. The balance was spanned using a 100-mg class "M" weight which read 107 mg (every day; weighed several times in a day). However, such an attempt resulted in obtaining negative weight gains (weight losses) after outlet sampling for 3 hours, 8 hours, and 13.51 hours. Precluding balance problems, it was considered that this could be due to evaporation losses of Apiezon-H grease at high stack temperatures (> 340° F) and/or the reaction of stack gases with substrate grease resulting in product(s) that showed volatility at stack temperatures.

The reaction with the stack gas is the most plausible explanation for the observed weight losses. The sample preparation has been used successfully at other low sulfur pulverized coal-fired boilers at the low 300° F temperature range. It is hypothesized that the Harrington flue gas contains gases, possibly chlorides, which may react with the hydrocarbons contained in the grease to cause weight losses via vaporization of reaction product(s).

For data retrieval purposes, grease losses have been assumed to be linear with the time of sampling. Based on the time of blank impactor runs and losses occurred on each impactor stage, each impactor stage of all outlet runs has been corrected with respect to time of sampling for such loss in weight. The corrected data for all runs are tabulated in Table 5. Such a correction for inlet sampling runs was considered unnecessary since only one 1-minute sample was collected and, thus, such grease evaporative losses would be negligible.

After returning from the field, the balance (Perkin-Elmer AD-2Z) was repaired, and then attempts were made to determine the true weight gains of impactor samplings at the Harrington power plant. None proved successful.

Table 4. Evaluation of Balance Bias at Different Weights*

Weight (mg)	Balance readout	Percent positive bias
10	10.7	+7
20	21.48	+7.4
20	21.42	+7.1
40	42.86	+7.15
50	53.57	+7.14
100	107.02	+7.02
150	160.54	+7.03

* The balance span was set to 107 with 100 mg because of the problem with the balance.

Table 5. Corrected Impactor Sampling Data[a]

RUN NO. 2 (outlet; sampling date-7/8/81; time-3 hrs)					RUN NO. 3 (outlet; sampling date-7/9/81; time-8 hrs)					RUN NO. 5 (outlet; sampling date-7/10/81; time-13 hrs 51 min)				
Stage number	Tare weight (mg)	Final weight (mg)	Correction[b]	Weight gain[c]	Stage number	Tare weight (mg)	Final weight (mg)	Correction[b]	Weight gain[c]	Stage number	Tare weight (mg)	Final weight (mg)	Correction[b]	Weight gain[c]
A	88.67	88.15	0.555	0.44	A	76.05	68.86	1.48	3.29	A	44.08	51.86	2.56	10.34
B	104.38	104.35	0.675	0.65	B	78.68	79.53	1.80	2.65	B	124.91	131.93	3.12	10.14
C	73.11	73.06	0.27	0.22	C	83.24	83.86	0.72	1.34	C	70.85	75.63	1.25	6.03
D	125.29	124.86	0.63	0.20	D	112.95	112.70	0.68	1.43	D	120.30	121.32	2.91	3.93
E	70.71	77.08	0.825	0.20	E	116.28	115.47	2.20	1.39	E	78.55	77.59	3.81	2.85
F	121.94	121.24	0.825	0.13	F	112.99	111.98	2.20	1.19	F	112.48	111.22	3.81	2.55
G	108.56	107.81	0.69	0.06	G	64.37	63.13	1.84	0.60	G	90.08	88.98	3.19	2.09
H	26.22	25.96	0.39	0.13	H	8.58	8.47	1.04	0.93	H	42.41	42.70	1.80	2.10

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[a] Inlet impactor Run No. 4 is not included because no corrections were required as sampling time was 1 min.

[b] Calculated using: $\text{Correction} = \dfrac{\text{blank stage negative weight x outlet impactor sampling time}}{\text{blank impactor sampling time}}$

[c] Weight gain = (final substrate weight after sampling + correction) - tare weight of the substrate.

Such attempts included determining the exact weight of the Apiezon-H grease on spare blank substrates prepared for sampling. It was believed that if the weight of grease on each substrate was constant and known, then the weight of the collected sample (weight gain) could be obtained by extracting the sample and grease together using an organic solvent from the substrate and weighing the disc. By this procedure, tare weight of the substrate would be known (W_1), the weight of the grease (W_2), and the weight of the disc + grease + sample (W_3). Then the weight of the sample (W_4) collected on each disc could be obtained by:

$$W_4 = W_3 - (W_2 + W_1).$$

However, the weight of the grease on 12 blank substrates showed a variation coefficient of ±1 mg which was considered intolerable, particularly when a fraction of a milligram of sample was collected on the lower stages of the impactor. Other unsuccessful attempts included isolation of only the sample from the substrate at controlled temperatures, leaving behind grease and determining soluble organics in the fly ash samples from Harrington Station. Excessive variability in the weights of grease or recovered sample obtained precluded the use of any of these approaches to deduce the sample weights.

The inlet size distributions obtained from impactor sampling on July 9, 1981, are included in Figure 2. Only one inlet or uncontrolled flue sample was collected. The mass data presented here were not corrected for grease losses because sampling time was 1 minute. The size distributions show an ill-defined bimodal nature (Figure 2). The larger mode appears between 2 to 3 μm and the smaller mode around 0.5 μm.

The outlet size distributions for three sampling days are presented in Figure 3. The particulate concentrations at the outlet were very low compared to inlet, and, hence, sampling times of 3 hours, 8 hours, and 13 hours and 51 minutes were used on July 8, 9, and 10, respectively. In spite of the longer sampling times, each of the impactor stages showed negative weight gains. Such losses, as mentioned earlier, would be due to reaction losses of Apiezon grease, and each of the substrates was corrected for grease losses as discussed earlier. In general, the shapes of the three curves are essentially the same, each showing a distinct submicron mode.

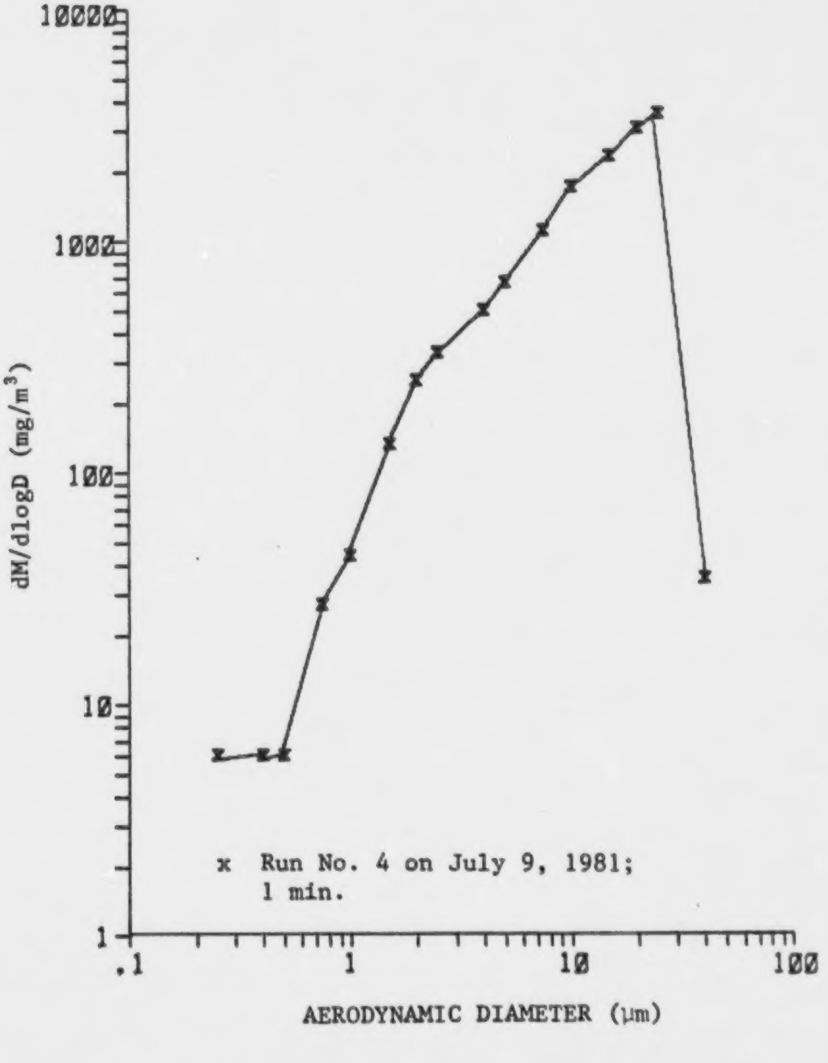

Figure 2. Inlet particle size distribution measured with MRI impactor.

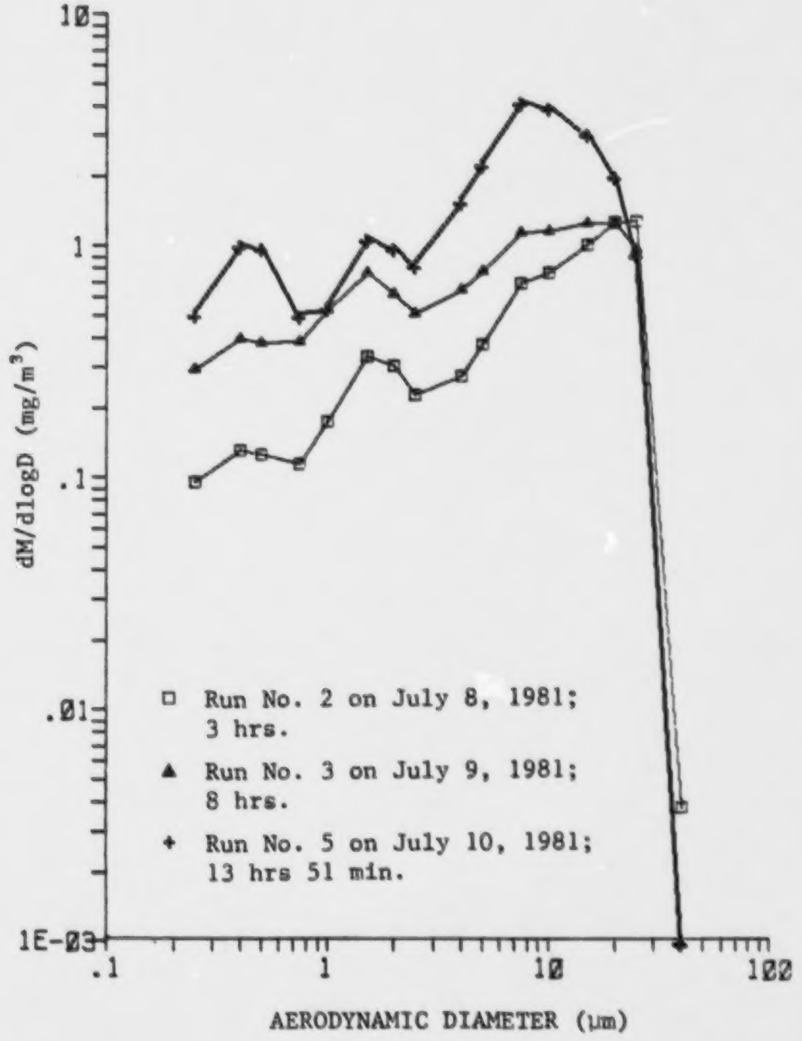

Figure 3. Particle size distribution measured with MRI impactor.

Figure 4 shows cumulative size distribution for three outlet samplings as a function of aerodynamic diameter. The shapes of the three curves are the same, and since none of the three distributions exhibits a straight line, the mass median aerodynamic diameter (MMAD) was obtained by interpolation from two points on either side of the 50 percent value. The MMADs obtained for July 8, 9, and 10 samplings were approximately 13, 7.5, and 9.5 μm, respectively. The variation in the MMADs between impactor tests may be due to the error introduced by substrate weight losses.

Penetration is the ratio of outlet to inlet, and size dependent penetration is obtained by dividing the outlet size distribution by the inlet size distribution. Since there was only one inlet size distribution, this was used to calculate penetrations for all three outlet sampling days (see Figure 5). The overall penetration (Table 1) was about 0.14 to 0.04 percent. In other words, the baghouse collected better than 99.86 percent of particulate matter from the flue gas. Figure 5 shows that, overall, the baghouse collected larger particles more efficiently than smaller particles. All three penetration curves show two peaks, one at around 0.36 μm and the other at 4.5 μm.

All the reduced impactor data are included in the Appendix.

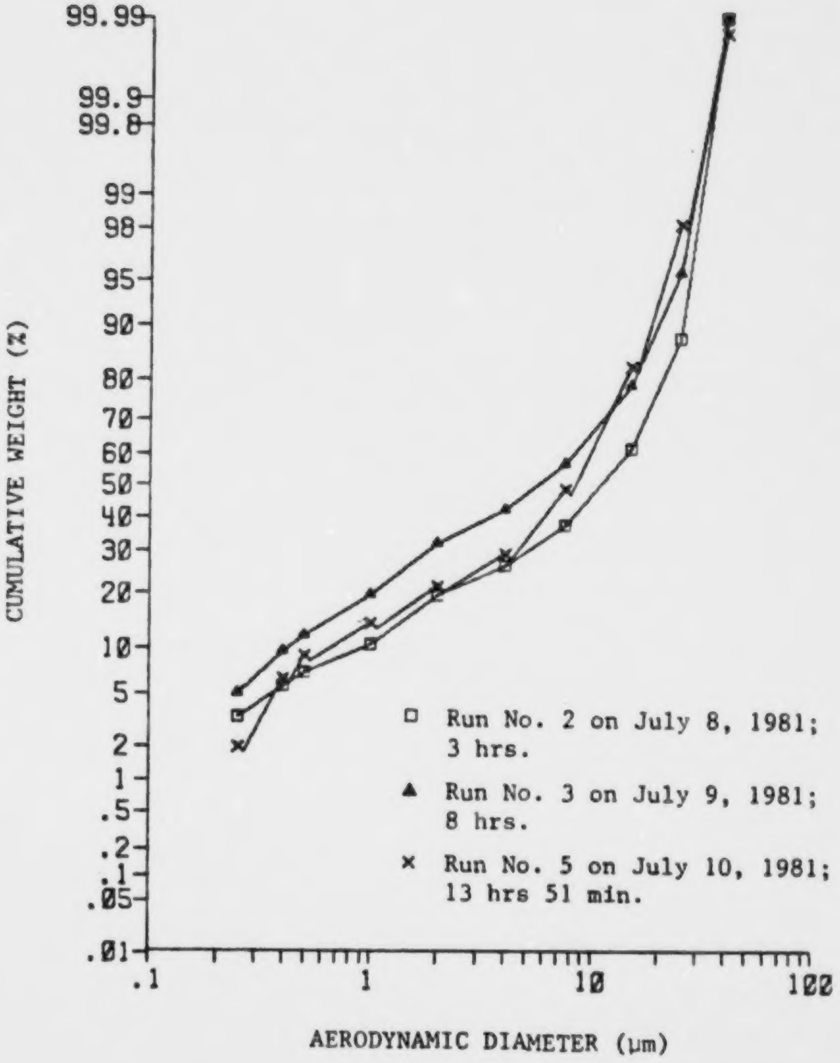

Figure 4. Cumulative mass size distribution for three outlet impactor samples.

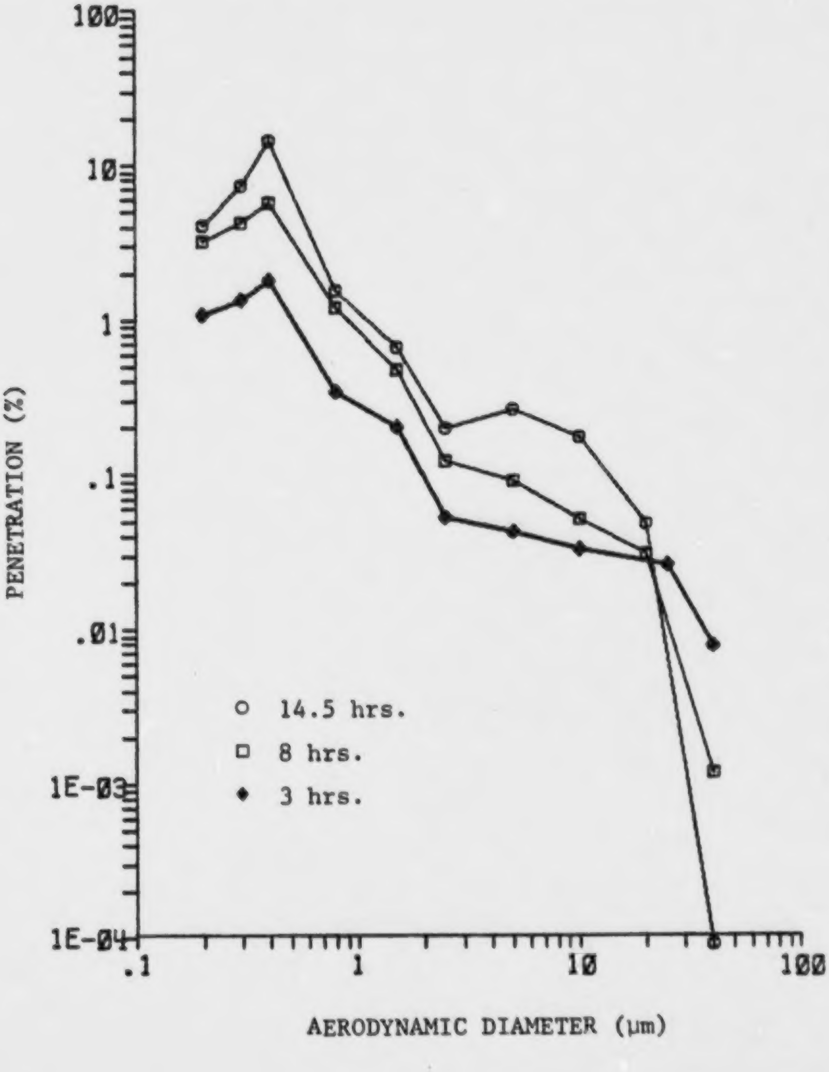

Figure 5. Particle size dependent particulate penetration through the baghouse.

SECTION 5

DATA QUALITY

Quality assurance efforts related to fine particle sampling emphasized substrate preparation, sampling, sample recovery techniques, and weighing operations. The substrates were prepared at RTI's home laboratory, sealed, and transported to the test site. Prior to a day of sampling, the required number of substrates were desiccated for at least 12 hours. A standard substrate control and substrates for sampling were weighed before loading into the impactor. The loaded impactor was sealed and carried to the testing site. After sampling, the samples were recovered in a clean room and desiccated for at least 24 hours before weighing. Sampled substrates were checked for constant weight over a period of two days.

During field weighings, it was observed that the Perkin-Elmer AD-2Z autobalance could not be calibrated using a standard class "M" weight. However, the balance during the field testing period of July 6-10, 1981, consistently read 100 mg weight as 107 mg. This positive (7 percent) error has been considered to cancel out since substrates were weighed before and after sampling under the condition when the balance exhibited the same degree of deviation from the true weight.

All impactor samplings have resulted in weight loss. This has been attributed to grease losses from reactions with the flue gas or evaporation as stack temperatures in excess of 330° F were encountered. Based on the losses of grease during a blank test run, all outlet samples were corrected for grease loss to obtain mass size distribution data.

REFERENCES

1. Cohen, J. J., and D.M. Montan. Theoretical Considerations, Design, and Evaluation of a Cascade Impactor. Am. Ind. Hyg. Assn. J., 28:95-104, 1967

2. Harris, D. B. Procedures for Cascade Impactor Calibration and Operation in Process Streams. EPA-600/2-77-004, U. S. Environmental Protection Agency, January 1977.

APPENDIX

```
    *****    I M P A C T O R    VER-3.0    *****

    *****    INPUT DATA    *****

DATE OF TEST      7/9/81
TIME OF TEST      2215
LOCATION OF TEST  SWPS AMARILLO STACK #3
TEST NUMBER        2
     SOURCE DESCRIPTION:  POWER PLANT
     SOURCE LOCATION:
     CONTROL DEVICE:      BAGHOUSE PULSE JET
     TEST PURPOSE:        PERFORMANCE EVALUATION
     TEST REMARKS:
     PART. DIAM. IS       IMP. AERO.
TEST TYPE         INLET
RUN NUMBER        4S - FILE NAME: T2R4S/IT
RUN REMARKS:
IMPACTOR TYPE     MRI1
                    MRI IMPACTOR WITH EPA CALIBRATION PARAMETERS

WATER VAPOR         4.23%  (FROM 'METH4')
CARBON DIOXIDE   12.13%  CARBON MONOXIDE   0.10%
OXYGEN            5.60%  NITROGEN         80.00%
PARTICLE DENSITY  2.40 GRAMS/CM

GAS METER VOLUME                 0.307 CUBIC FEET
IMPACTOR DELTA P                 1.54  INCHES HG (CALCULATED)
ORIFICE DELTA P                  0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)     -0.20  INCHES H2O
BAROMETRIC PRESS.               26.94  INCHES HG
STACK TEMPERATURE              343     DEGREES F
METER TEMPERATURE               75     DEGREES F
IMPACTOR TEMPERATURE           343     DEGREES F
SAMPLE TIME                      1.00  MINUTES
AVERAGE VELOCITY OF GAS       5994.00  FEET/MINUTE
NOZZLE DIAMETER                 0.1250 INCHES
MAXIMUM AERODYN. DIAMETER      60.00   MICRONS

MASS GAIN ON STAGE  1           11.77 MG
MASS GAIN ON STAGE  2            1.32 MG
MASS GAIN ON STAGE  3            2.07 MG
MASS GAIN ON STAGE  4            1.46 MG
MASS GAIN ON STAGE  5            0.53 MG
MASS GAIN ON STAGE  6            0.19 MG
MASS GAIN ON STAGE  7            0.03 MG
MASS GAIN ON FINAL FILTER        0.56 MG
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    ***    RESULTS    ***

DATE OF TEST      7/9/81
TIME OF TEST      2215
LOCATION OF TEST  SWPS AMARILLO STACK #3
TEST NUMBER        2  -
RUN NUMBER        45
ACTUAL FLOW RATE (STACK CONDITIONS)    0.481 CFM
FLOW RATE (STANDARD CONDITIONS)        0.273 CFM
PERCENT ISOKINETIC SAMPLING           94.14  %

VISCOSITY OF GAS STREAM                0.0002317 GRAMS/CM-SEC
STAGE          CCF           DP(PHYSICAL )  DP(IMP.AERO)   CUM FRACTION
  1           1.046             6.053          9.591          0.3436
  2           1.041             6.836         10.804          0.2699
  3           1.077             3.622          5.824          0.1545
  4           1.167             1.668          2.791          0.0731
  5           1.309             0.914          1.621          0.0435
  6           1.885             0.347          0.739          0.0329
  7           2.602             0.213          0.532          0.0312

NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
      THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

TOTAL MASS PER DRY NORMAL CUBIC METER 2424.4600 MG/CUBIC METER

IMP. AERO.
PARTICLE SIZE  CUMFR          CUMFR          CUM.MASS       DM/DLOGD        DV/DLOGD
 (MICRONS)     (STD. DEV.)    (PER CENT)        (MG/DRY N.CU.METER)

 0.20          -1.8793         3.0            72.9908         6.4735
 0.25          -1.8757         3.0            73.5935         6.5178
 0.40          -1.8680         3.1            74.8764         6.6118
 0.50          -1.8644         3.1            75.4919         6.6568
 0.75          -1.8391         3.3            79.9031        30.3824
 1.00          -1.8146         3.5            84.3694        50.1693
 1.50          -1.7367         4.1            99.9327       152.7190
 2.00          -1.6248         5.2           126.3040       290.7030
 2.50          -1.5124         6.5           158.1110       391.9000
 4.00          -1.2573        10.4           252.8910       605.3790
 5.00          -1.1216        13.1           317.6000       804.0580
 7.50          -0.8205        20.6           499.3590      1367.3800
10.00          -0.5676        28.5           691.3950      2139.3500
15.00          -0.1057        45.8          1110.1600      2910.7600
20.00           0.3158        62.4          1512.6400      3879.1400
25.00           0.7969        78.7          1908.6800      4541.8200
40.00           3.6123       100.0          2424.0900        45.4937
50.00          10.3941       100.0          2424.4600         0.0000
```

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  ***   RESULTS (CONTINUED)   ***

TIME OF TEST      2215
LOCATION OF TEST  SWPS AMARILLO STACK #3
TEST NUMBER        2
RUN NUMBER        45

LOG-NORMAL SIZE DISTRIBUTION PARAMETERS

LEAST SQUARES LINE :    Y- 1.74- 0.98X
MASS GEOMETRIC MEAN DIAMETER     60.208
GEOMETRIC STANDARD DEVIATION     10.505
CORRELATION COEFFICIENT           0.918
CUM. MASS LESS THAN  0.0 MICRON: %1212.24 MG/DRY NORMAL CU.METER ( 50.0 %)
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    *****    I M P A C T O R    VER-3.0    *****

    *****    INPUT DATA    *****

DATE OF TEST      7/8/81
TIME OF TEST      1130
LOCATION OF TEST  SWPS AMARILLO STACK #3
TEST NUMBER        2
     SOURCE DESCRIPTION:  POWER PLANT
     SOURCE LOCATION:
     CONTROL DEVICE:      BAGHOUSE PULSE JET
     TEST PURPOSE:        PERFORMANCE EVALUATION
     TEST REMARKS:
     PART. DIAM. IS       IMP. AERO.
TEST TYPE         OUTLET
RUN NUMBER        2S - FILE NAME: T2R2S/OT
RUN REMARKS:
IMPACTOR TYPE     MRI1
                    MRI IMPACTOR WITH EPA CALIBRATION PARAMETERS

WATER VAPOR        4.23%  (FROM 'METH4')
CARBON DIOXIDE   12.13%  CARBON MONOXIDE   0.10%
OXYGEN            5.60%  NITROGEN         80.00%
PARTICLE DENSITY  2.40 GRAMS/CM

GAS METER VOLUME              %112.358 CUBIC FEET
IMPACTOR DELTA P                 6.13  INCHES HG (CALCULATED)
ORIFICE DELTA P                  2.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)     -0.20  INCHES H2O
BAROMETRIC PRESS.               26.88  INCHES HG
STACK TEMPERATURE              333     DEGREES F
METER TEMPERATURE               84     DEGREES F
IMPACTOR TEMPERATURE           333     DEGREES F
SAMPLE TIME                    180.00  MINUTES
AVERAGE VELOCITY OF GAS       5994.00  FEET/MINUTE
NOZZLE DIAMETER                0.1875  INCHES
MAXIMUM AERODYN. DIAMETER       60.00  MICRONS

MASS GAIN ON STAGE  1              1.10 MG
MASS GAIN ON STAGE  2              0.65 MG
MASS GAIN ON STAGE  3              0.22 MG
MASS GAIN ON STAGE  4              0.20 MG
MASS GAIN ON STAGE  5              0.20 MG
MASS GAIN ON STAGE  6              0.13 MG
MASS GAIN ON STAGE  7              0.06 MG
MASS GAIN ON FINAL FILTER          0.13 MG
```

```
      ***   RESULTS   ***

DATE OF TEST       7/8/81
TIME OF TEST       1130
LOCATION OF TEST  SWPS AMARILLO STACK #3
TEST NUMBER         2 -
RUN NUMBER         25
ACTUAL FLOW RATE (STACK CONDITIONS)     0.954 CFM
FLOW RATE (STANDARD CONDITIONS)         0.547 CFM
PERCENT ISOKINETIC SAMPLING            83.03  %

VISCOSITY OF GAS STREAM                 0.0002295 GRAMS/CM-SEC
STAGE           CCF            DP(PHYSICAL )  DP(IMP.AERO)   CUM FRACTION
   1           1.065              4.240          6.778          0.5888
   2           1.057              4.793          7.635          0.3477
   3           1.109              2.521          4.113          0.2654
   4           1.243              1.141          1.971          0.1907
   5           1.471              0.607          1.141          0.1178
   6           2.658              0.203          0.512          0.0710
   7           5.978              0.090          0.340          0.0486

NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
      THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

TOTAL MASS PER DRY NORMAL CUBIC METER    1.0022 MG/CUBIC METER

IMP. AERO.
PARTICLE SIZE  CUMFR          CUMFR          CUM.MASS        DM/DLOGD        DV/DLOGD
  (MICRONS)    (STD. DEV.)    (PER CENT)       (MG/DRY N.CU.METER)

  0.20          -1.9481        2.6           0.0258          0.0784
  0.25          -1.8267        3.4           0.0340          0.0986
  0.40          -1.5783        5.7           0.0574          0.1347
  0.50          -1.4777        7.0           0.0699          0.1300
  0.75          -1.3441        8.9           0.0896          0.1180
  1.00          -1.2458       10.6           0.1066          0.1788
  1.50          -1.0297       15.2           0.1519          0.3444
  2.00          -0.8683       19.3           0.1930          0.3106
  2.50          -0.7808       21.7           0.2179          0.2336
  4.00          -0.6366       26.2           0.2628          0.2808
  5.00          -0.5438       29.3           0.2939          0.3857
  7.50          -0.3139       37.7           0.3776          0.7016
 10.00          -0.0871       46.5           0.4663          0.7887
 15.00           0.2955       61.6           0.6175          1.0347
 20.00           0.6908       75.5           0.7568          1.2920
 25.00           1.1691       87.9           0.8807          1.3122
 40.00           4.0275      100.0           1.0021          0.0039
 50.00          10.0532      100.0           1.0022          0.0000
```

```
   ***  RESULTS (CONTINUED)   ***

TIME OF TEST       1130
LOCATION OF TEST  SWPS AMARILLO STACK #3
TEST NUMBER         2
RUN NUMBER         25

LOG-NORMAL SIZE DISTRIBUTION PARAMETERS

LEAST SQUARES LINE :    Y- 1.20- 0.97X
MASS GEOMETRIC MEAN DIAMETER     17.417
GEOMETRIC STANDARD DEVIATION     10.774
CORRELATION COEFFICIENT           0.997
CUM. MASS LESS THAN  0.0 MICRON:   0.50 MG/DRY NORMAL CU.METER ( 50.0 %)
```

```
  *****    I M P A C T O R    VER-3.0    *****

   *****    INPUT DATA    *****

DATE OF TEST      7/9/81
TIME OF TEST      10:10
LOCATION OF TEST  SWPS AMARILLO STACK NO 3
TEST NUMBER        2
     SOURCE DESCRIPTION:  POWER PLANT
     SOURCE LOCATION:
     CONTROL DEVICE:      BAGHOUSE PULSE JET
     TEST PURPOSE:        PERFORMANCE EVALUATION
     TEST REMARKS:
     PART. DIAM. IS       IMP. AERO.
TEST TYPE         OUTLET
RUN NUMBER        3S - FILE NAME: T2R3S/OT
RUN REMARKS:      N
IMPACTOR TYPE     MRI1
                    MRI IMPACTOR WITH EPA CALIBRATION PARAMETERS

WATER VAPOR        4.23%  (FROM 'METH4')
CARBON DIOXIDE   12.13%  CARBON MONOXIDE   0.10%
OXYGEN            5.60%  NITROGEN         80.00%
PARTICLE DENSITY  2.40 GRAMS/CM

GAS METER VOLUME               %345.333 CUBIC FEET
IMPACTOR DELTA P                  7.82  INCHES HG (CALCULATED)
ORIFICE DELTA P                   2.80  INCHES H20
STACK PRESS. (BELOW ATMOS.)      -0.20  INCHES H20
BAROMETRIC PRESS.                27.02  INCHES HG
STACK TEMPERATURE               300     DEGREES F
METER TEMPERATURE                85     DEGREES F
IMPACTOR TEMPERATURE            300     DEGREES F
SAMPLE TIME                     480.00  MINUTES
AVERAGE VELOCITY OF GAS        5994.00  FEET/MINUTE
NOZZLE DIAMETER                 0.1875  INCHES
MAXIMUM AERODYN. DIAMETER        60.00  MICRONS

MASS GAIN ON STAGE  1               3.69 MG
MASS GAIN ON STAGE  2               2.65 MG
MASS GAIN ON STAGE  3               1.34 MG
MASS GAIN ON STAGE  4               1.43 MG
MASS GAIN ON STAGE  5               1.39 MG
MASS GAIN ON STAGE  6               1.19 MG
MASS GAIN ON STAGE  7               0.60 MG
MASS GAIN ON FINAL FILTER           0.93 MG
```

```
    ***    RESULTS    ***

DATE OF TEST       7/9/81
TIME OF TEST       10:10
LOCATION OF TEST   SWPS AMARILLO STACK NO 3
TEST NUMBER         2  -
RUN NUMBER         3S      Δ
ACTUAL FLOW RATE (STACK CONDITIONS)    1.055 CFM
FLOW RATE (STANDARD CONDITIONS)        0.634 CFM
PERCENT ISOKINETIC SAMPLING           91.79  %

VISCOSITY OF GAS STREAM                0.0002224 GRAMS/CM-SEC
STAGE           CCF          DP(PHYSICAL )  DP(IMP.AERO)    CUM FRACTION
  1            1.065            3.969         6.347           0.7209
  2            1.058            4.486         7.148           0.5204
  3            1.110            2.359         3.851           0.4191
  4            1.245            1.067         1.845           0.3109
  5            1.478            0.567         1.068           0.2057
  6            2.745            0.185         0.476           0.1157
  7            7.388            0.073         0.306           0.0703

NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
      THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

TOTAL MASS PER DRY NORMAL CUBIC METER    1.6019 MG/CUBIC METER

IMP. AERO.
PARTICLE SIZE   CUMFR            CUMFR          CUM.MASS         DM/DLOGD        DV/DLOGD
  (MICRONS)     (STD. DEV.)      (PER CENT)       (MG/DRY N.CU.METER)

x ~~0.20~~      -1.7879           3.7           0.0591           0.2301
  ~~0.25~~      -1.6226           5.2           0.0838           0.3051
x  0.40         -1.2978           9.7           0.1556           0.4114
   0.50         -1.1705          12.1           0.1936           0.3961
x  0.75         -0.9888          16.1           0.2585           0.4018
   1.00         -0.8561          19.6           0.3139           0.5506
   1.50         -0.6126          27.0           0.4326           0.7918
   2.00         -0.4534          32.5           0.5208           0.6396
   2.50         -0.3628          35.8           0.5741           0.5250
   4.00         -0.1874          42.6           0.6818           0.6695
   5.00         -0.0785          46.9           0.7508           0.8025
   7.50          0.1797          57.1           0.9152           1.1730
  10.00          0.4107          65.9           1.0562           1.1915
  15.00          0.8044          78.9           1.2646           1.2895
  20.00          1.2116          88.7           1.4211           1.2926
x 25.00          1.7011          95.6           1.5306           0.9973
  ~~40.00~~      4.5895         100.0           1.6019           0.0006
x 50.00         11.4323         100.0           1.6019           0.0000
```

```
   ***   RESULTS (CONTINUED)   ***

TIME OF TEST       10:10
LOCATION OF TEST  SWPS AMARILLO STACK NO 3
TEST NUMBER         2
RUN NUMBER         3S

LOG-NORMAL SIZE DISTRIBUTION PARAMETERS

LEAST SQUARES LINE :     Y- 0.85- 1.14X
MASS GEOMETRIC MEAN DIAMETER       5.553
GEOMETRIC STANDARD DEVIATION       7.509
CORRELATION COEFFICIENT            0.997
CUM. MASS LESS THAN  0.0 MICRON:   0.00 MG/DRY NORMAL CU.METER ( 50.0 %)
```

```
  *****    I M P A C T O R    VER 1.0    *****

  *****    INPUT DATA    *****

DATE OF TEST  : 7/10/81
TIME OF TEST     1038
LOCATION OF TEST  SWPS AMARILLO STACK #3
TEST NUMBER        2
    SOURCE DESCRIPTION   POWER PLANT
    SOURCE LOCATION
    CONTROL DEVICE        BAGHOUSE PULSE JET
    TEST PURPOSE          PERFORMANCE EVALUATION
    TEST REMARKS
    PART. DIAM. IS        IMP. AERO.
TEST TYPE          OUTLET
RUN NUMBER         3S - FILE NAME  T2R3S-OT
RUN REMARKS
IMPACTOR TYPE      MRI
                     MRI IMPACTOR WITH EPA CALIBRATION PARAMETERS

WATER VAPOR        4.23%  (FROM METH4)
CARBON DIOXIDE   12.13%  CARBON MONOXIDE   0.10%
OXYGEN            5.20%  NITROGEN          82.00%
PARTICLE DENSITY  2.40 GRAMS/CM

GAS METER VOLUME                  15[illegible] CUBIC FEET
IMPACTOR DELTA P                   6.11  INCHES H2O (CALCULATED)
ORIFICE DELTA P                    [illegible].00  INCHES H2O
STACK PRESS (BELOW BARO.)         -0.20  INCHES H2O
BAROMETRIC PRESS                  26.90  INCHES HG
STACK TEMPERATURE                 170     DEGREES F
METER TEMPERATURE                  90     DEGREES F
IMPACTOR TEMPERATURE              170     DEGREES F
SAMPLE TIME                       2[illegible]1.00  MINUTES
AVERAGE VELOCITY OF GAS         5040.00  FEET/MINUTE
NOZZLE DIAMETER                   0.1875  INCHES
MAXIMUM AERODYN. DIAMETER        60.00  MICRONS

 MASS GAIN ON STAGE  1             11.76 MG
 MASS GAIN ON STAGE  2             10.1[illegible] MG
 MASS GAIN ON STAGE  3              6.41 MG
 MASS GAIN ON STAGE  4              2.92 MG
 MASS GAIN ON STAGE  5              2.85 MG
 MASS GAIN ON STAGE  6              2.58 MG
 MASS GAIN ON STAGE  7              3.69 MG
 MASS GAIN ON FINAL FILTER          2.18 MG
```

```
     *****    I M P A C T O R    VER-3.0     *****

     *****    INPUT DATA    *****

DATE OF TEST   "  7/10/81
TIME OF TEST      1038
LOCATION OF TEST  SWPS AMARILLO STACK #3
TEST NUMBER         2
     SOURCE DESCRIPTION:  POWER PLANT
     SOURCE LOCATION:
     CONTROL DEVICE:      BAGHOUSE PULSE JET
     TEST PURPOSE:        PERFORMANCE EVALUATION
     TEST REMARKS:
     PART. DIAM.  IS      IMP. AERO.
TEST TYPE         OUTLET
RUN NUMBER        55 - FILE NAME: T2R55/OT
RUN REMARKS:
IMPACTOR TYPE     MRI1
                    MRI IMPACTOR WITH EPA CALIBRATION PARAMETERS

WATER VAPOR        4.23%  (FROM 'METH4')
CARBON DIOXIDE   12.13%  CARBON MONOXIDE    0.10%
OXYGEN            5.60%  NITROGEN          80.00%
PARTICLE DENSITY  2.40 GRAMS/CM

GAS METER VOLUME               %523.052 CUBIC FEET
IMPACTOR DELTA P                  6.11  INCHES HG (CALCULATED)
ORIFICE DELTA P                   2.80  INCHES H2O
STACK PRESS. (BELOW ATMOS.)      -0.20  INCHES H2O
BAROMETRIC PRESS.                26.98  INCHES HG
STACK TEMPERATURE              330      DEGREES F
METER TEMPERATURE               90      DEGREES F
IMPACTOR TEMPERATURE           330      DEGREES F
SAMPLE TIME                    831.00   MINUTES
AVERAGE VELOCITY OF GAS       5940.00   FEET/MINUTE
NOZZLE DIAMETER                  0.1875 INCHES
MAXIMUM AERODYN. DIAMETER       60.00   MICRONS

MASS GAIN ON STAGE  1            11.76 MG
MASS GAIN ON STAGE  2            10.14 MG
MASS GAIN ON STAGE  3             6.03 MG
MASS GAIN ON STAGE  4             3.93 MG
MASS GAIN ON STAGE  5             2.85 MG
MASS GAIN ON STAGE  6             2.55 MG
MASS GAIN ON STAGE  7             2.09 MG
MASS"GAIN ON FINAL FILTER         2.10 MG
```

```
    ***    RESULTS    ***

DATE OF TEST       7/10/81
TIME OF TEST       1038
LOCATION OF TEST   SWPS AMARILLO STACK #3
TEST NUMBER         2  -
RUN NUMBER         5S
ACTUAL FLOW RATE (STACK CONDITIONS)     0.951 CFM
FLOW RATE (STANDARD CONDITIONS)         0.549 CFM
PERCENT ISOKINETIC SAMPLING            83.47  %

VISCOSITY OF GAS STREAM                 0.0002289 GRAMS/CM-SEC
STAGE          CCF               DP(PHYSICAL )  DP(IMP.AERO)   CUM FRACTION
  1           1.064                4.243          6.782          0.7163
  2           1.057                4.796          7.639          0.4717
  3           1.108                2.523          4.115          0.3262
  4           1.240                1.143          1.972          0.2314
  5           1.466                0.609          1.142          0.1626
  6           2.632                0.204          0.512          0.1011
  7           5.864                0.091          0.341          0.0507

NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
      THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

TOTAL MASS PER DRY NORMAL CUBIC METER    3.3513 MG/CUBIC METER

IMP. AERO.
PARTICLE SIZE   CUMFR          CUMFR          CUM.MASS        DM/DLOGD        DV/DLOGD
  (MICRONS)     (STD. DEV.)    (PER CENT)       (MG/DRY N.CU.METER)

  0.20          -2.3036          1.1          0.0356          0.2823
  0.25          -2.0253          2.1          0.0718          0.5157
  0.40          -1.4815          6.9          0.2320          1.0182
  0.50          -1.2923          9.8          0.3288          0.9961
  0.75          -1.1044         13.5          0.4514          0.5103
  1.00          -1.0269         15.2          0.5102          0.5466
  1.50          -0.8620         19.4          0.6513          1.0875
  2.00          -0.7283         23.3          0.7816          0.9926
  2.50          -0.6495         25.8          0.8647          0.8418
  4.00          -0.4660         32.1          1.0745          1.5725
  5.00          -0.3198         37.5          1.2553          2.2851
  7.50           0.0609         52.4          1.7571          4.2098
 10.00           0.4446         67.2          2.2510          3.9863
 15.00           1.0482         85.3          2.8578          3.0985
 20.00           1.6004         94.5          3.1678          2.0109
 25.00           2.2002         98.6          3.3047          0.9281
 40.00           5.3148        100.0          3.3513          0.0000
 50.00          12.2621        100.0          3.3513          0.0000
```

```
   ***   RESULS (CONTINUED)   ***

TIME OF TEST       1038
LOCATION OF TEST  SWPS AMARILLO STACK #3
TEST NUMBER         2
RUN NUMBER         5S
LOG-NORMAL SIZE DISTRIBUTION PARAMETERS

LEAST SQUARES LINE :    Y- 1.05- 1.11X
MASS GEOMETRIC MEAN DIAMETER       8.865
GEOMETRIC STANDARD DEVIATION       7.972
CORRELATION COEFFICIENT            0.985
CUM. MASS LESS THAN  0.0 MICRON:   1.68 MG/DRY NORMAL CU.METER ( 50.0 %)
```

```
*****      E F F I C I E N C Y    VER 3.0    *****

INLET FILE NAME: T2R4S/IT
    DATE/TIME: 7/9/81   2215
    LOCATION:  SWPS -

OUTLET FILE NAME: T2R2S/OT
    DATE/TIME: 7/8/81   1130
    LOCATION:  SWPS AMARILLO STACK #3 -

IMP. AERO.
DIAMETER        % PENETRATION  % EFFIC.        90% CONFIDENCE
 0.2                1.2128        98.7872         N/A
 0.3                1.5149        98.4851         N/A
 0.4                2.0392        97.9608         N/A
 0.5                1.9555        98.0445         N/A
 0.8                0.3884        99.6117         N/A
 1.0                0.3564        99.6436         N/A
 1.5                0.2255        99.7745         N/A
 2.0                0.1068        99.8932         N/A
 2.5                0.0596        99.9404         N/A
 4.0                0.0464        99.9536         N/A
 5.0                0.0480        99.9520         N/A
 7.5                0.0513        99.9487         N/A
10.0                0.0369        99.9631         N/A
15.0                0.0356        99.9644         N/A
20.0                0.0334        99.9666         N/A
25.0                0.0291        99.9709         N/A
40.0                0.0088        99.9912         N/A
50.0                0.0003        99.9997         N/A
TOTAL MASS          0.0415        99.9585         N/A
```

```
*****        E F F I C I E N C Y    VER 3.0    *****

INLET FILE NAME: T2R4S/IT
    DATE/TIME: 7/9/81   2215
    LOCATION:  SWPS -

OUTLET FILE NAME: T2R3S/OT
    DATE/TIME: 7/9/81   10:10
    LOCATION:  SWPS AMARILLO STACK NO 3 - N

IMP. AERO.
DIAMETER           % PENETRATION   % EFFIC.       90% CONFIDENCE
 0.2                    3.5592       96.4408          N/A
 0.3                    4.6857       95.3143          N/A
 0.4                    6.2291       93.7709          N/A
 0.5                    5.9573       94.0427          N/A
 0.8                    1.3228       98.6772          N/A
 1.0                    1.0975       98.9025          N/A
 1.5                    0.5185       99.4815          N/A
 2.0                    0.2200       99.7800          N/A
 2.5                    0.1340       99.8661          N/A
 4.0                    0.1106       99.8894          N/A
 5.0                    0.0998       99.9002          N/A
 7.5                    0.0858       99.9142          N/A
10.0                    0.0557       99.9443          N/A
15.0                    0.0444       99.9556          N/A
20.0                    0.0335       99.9666          N/A
25.0                    0.0221       99.9779          N/A
40.0                    0.0013       99.9987          N/A
50.0                    0.0000      100.0000          N/A
TOTAL MASS              0.0663       99.9337          N/A
```

```
    *****       E F F I C I E N C Y    VER 3.0    *****

INLET FILE NAME: T2R4S/IT
    DATE/TIME: 7/9/81   2215
    LOCATION:  SWPS -

OUTLET FILE NAME: T2R5S/OT
    DATE/TIME: 7/10/81   1038
    LOCATION:  SWPS AMARILLO STACK #3 -

IMP. AERO.
DIAMETER        % PENETRATION  % EFFIC.        90% CONFIDENCE
 0.2                4.3662       95.6338         N/A
 0.3                7.9211       92.0789         N/A
 0.4               15.4185       84.5815         N/A
 0.5               14.9818       85.0182         N/A
 0.8                1.6798       98.3202         N/A
 1.0                1.0896       98.9104         N/A
 1.5                0.7121       99.2879         N/A
 2.0                0.3414       99.6586         N/A
 2.5                0.2148       99.7852         N/A
 4.0                0.2598       99.7402         N/A
 5.0                0.2842       99.7158         N/A
 7.5                0.3079       99.6921         N/A
10.0                0.1864       99.8137         N/A
15.0                0.1066       99.8934         N/A
20.0                0.0521       99.9479         N/A
25.0                0.0206       99.9794         N/A
40.0                0.0001       99.9999         N/A
50.0                0.0000      100.0000         N/A
TOTAL MASS          0.1388       99.8612         N/A
```

APPENDIX 6

Coal Analysis Results

REPORT OF ANALYSIS

Lab No. 162198
Sample of Coal
Harrington Unit 3 Run 2 - 8/26/81
From ETS, Inc., Roanoke, VA

	As Rec'd.	Dry Coal
Moisture	23.76%	-----%
Ash	5.63%	7.39%
Sulphur	.43%	.57%
BTU	8,927	11,709
Carbon	-----	
Hydrogen	-----	
Nitrogen	-----	
Oxygen	-----	

REPORT OF ANALYSIS

Lab No. 162199
Sample of Coal
Harrington Unit 3 Run 3 - 8/26/81
From ETS, Inc., Roanoke, VA

	As Rec'd.	Dry Coal
Moisture	23.77%	-----%
Ash	6.56%	6.82%
Sulphur	.51%	.53%
BTU	8,904	11,680
Carbon	-----	
Hydrogen	-----	
Nitrogen	-----	
Oxygen	-----	

REPORT OF ANALYSIS

Lab No. 162196
Sample of Coal
Harrington Unit 3 Run 4 - 8/26/81
From ETS, Inc., Roanoke, VA

	As Rec'd.	Dry Coal
Moisture	27.11%	-----%
Ash	4.84%	6.64%
Sulphur	.39%	.54%
BTU	8,730	11,977
Carbon	-----	
Hydrogen	-----	
Nitrogen	-----	
Oxygen	-----	

REPORT OF ANALYSIS

Lab No. 162201
Sample of Coal
Harrington Unit 3 Run 5 - 8/26/81
From ETS, Inc., Roanoke, VA

	As Rec'd.	Dry Coal
Moisture	24.66%	-----%
Ash	4.76%	6.32%
Sulphur	.35%	.47%
BTU	8,770	11,640
Carbon	-----	
Hydrogen	-----	
Nitrogen	-----	
Oxygen	-----	

APPENDIX 7

Bag Analysis Results

ETS, INC.

FABRIC TEST WORKORDER

P. O. No. EPA 68-02-3649 Contract No. 80-138 (S4-80-138)

ETS Specimen Nos. Covered by Workorder 81-169, 81-170

Date Workorder Issued 9/8/81

* * *

COMPANY

Name EPA - SWPS

Address

Person(s) to Contact Phone No.

Date Received Date Shipped

* * *

TESTS TO BE PERFORMED

	Permeability			Tensile Strength		Mullen Burst	MIT Flex		LOI	Special Requirements
	As Is	Vac@ "	Vac@ "	Warp	Fill		Warp	Fill		
Top	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	Visual Inspection Required Yes(X) No( )
Middle	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	
Bottom	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	Bahco Required Yes( ) No(X)
*Other	(X)	( )	( )	( )	( )	( )	( )	( )	( )	
Priority	( )	( )	( )	( )	( )	( )	( )	( )	( )	
Number of Samples	4									Microscopic Exam Required Yes( ) No(X)
Dates Required	9/20/81									

* * *

Pertinent Information

*Other Test(s) Required (1)pH of ash on dirty bags (2)acid flex on clean bags

Test Requested by J. McKenna

Test Authorized by J. McKenna

ETS111 (04/29/82)

SUMMARY OF FABRIC FILTER TEST DATA

P.O. No.: ____________
Bag Material: Glass (Tef B)
Contract No: S80-138
Bag Condition: Used
ETS Specimen No: 81-202
Fabric wt., oz/yd^2 ____________
Customer No: ____________
Type of Weave: ____________
Customer: SWPS
Date: ____________

	BAG SAMPLE Top	BAG SAMPLE Middle	BAG SAMPLE Bottom	Average	New Bag
Permeability, FPM					
As Received	1.9	2.0	1.8	1.9	57.4
After 10 " Vacuum	20.9	40.6	34.0	31.8	
After 30 " Vacuum	34.8	46.4	38.2	39.8	
Other					
Mullen Burst, PSI	252	255	277	261	343
L.O.I., wt. %					

	W	F	W	F	W	F	W	F	W	F
Tensile, lb./in	140	52	201	69	157	92	166	71	228	87
MIT FLEX	2287	104	1726	74	1786	68	1933	82	9946	629

Dust Sample

pH		11.7
wt.% ash		

SUMMARY OF FABRIC FILTER TEST DATA

P.O. No.: ____________ Bag Material: Glass (Tef B)

Contract No: S80-138 Bag Condition: New

ETS Specimen No: 81-169 Fabric wt., oz/yd^2 ________

Customer No: ____________ Type of Weave: ____________

Customer: SWPS Date: ____________

Bag Spec - W. W. Criswell 442-57DC2
150 ½ fill 150 ¼ Warp 10% Tef B Texturized

BAG SAMPLE

	Top	Middle	Bottom	Average	New Bag
Permeability, FPM					
As Received	56.1	59.3	56.8	57.4	
After ___" Vacuum					
After ___" Vacuum					
Other					
Mullen Burst, PSI	312	367	350	343	
L.O.I., wt. %		9.93	10.03	10.0	

	W	F	W	F	W	F	W	F	W	F
Tensile, lb./in	222	89	225	86	237	87	228	87		
MIT FLEX	8998	461	12092	847	8749	578	9946	629		
Acid Flex							0	0		

Dust Sample

pH ____________

wt.% ash ____________

SUMMARY OF FABRIC FILTER TEST DATA

P.O. No.: ______ Bag Material: Glass (625 Finish)

Contract No: S80-138 Bag Condition: Used

ETS Specimen No: 81-201 Fabric wt., oz/yd^2 ______

Customer No: ______ Type of Weave: ______

Customer: SWPS Date: ______

	BAG SAMPLE									
	Top		Middle		Bottom		Average		New Bag	
Permeability, FPM										
As Received	2.1		1.2		1.5		1.6		56.1	
After 10 " Vacuum	34.8		23.9		38.6		32.4			
After 30 " Vacuum	46.5		33.5		60.4		46.8			
Other										
Mullen Burst, PSI	412		427		420		420		619	
L.O.I., wt. %									—	
	W	F	W	F	W	F	W	F	W	F
Tensile, lb./in	360	135	341	139	268	158	323	144	465	252
MIT FLEX	9185	1277	5878	1281	8679	887	7944	1148	10406	3013
Dust Sample										
pH							11.7			
wt.% ash										

SUMMARY OF FABRIC FILTER TEST DATA

P.O. No.: ______ Bag Material: Glass (625 Finish)

Contract No: S80-138 Bag Condition: New

ETS Specimen No: 81-170 Fabric wt., oz/yd^2 14.0

Customer No: ______ Type of Weave: ______

Customer: SWPS Date: ______

Bag Spec. Criswell Burlington 449 COF II
Fill 75 1/3 Warp 75 ½ Texturized Combined with 15 1/6 singles

	BAG SAMPLE Top	Middle	Bottom	Average	New Bag
Permeability, FPM					
As Received	53.6	55.5	59.3	56.1	—
After ___" Vacuum					
After ___" Vacuum					
Other					
Mullen Burst, PSI	615	605	637	619	—
L.O.I., wt. %		3.75	3.76	3.76	—

	W	F	W	F	W	F	W	F	W	F
Tensile, lb./in	483	249	460	233	454	275	465	252		
MIT FLEX	10138	2996	11203	2860	9876	3183	10406	3013		
Acid Felx							319	410		

Dust Sample

pH ______

wt.% ash ______

APPENDIX 8

Equipment Calibration Data

ETS, INC.

METER CONSOLE CALIBRATION FORM

Meter Box No. Aztec Barometric Pressure, P_B 30.19 in.Hg

Test Meter No. ________ Date 6-26-81

Run No.	1	2	3	4	5	6	
Orifice Setting, ΔH	.5	1	2	4			
Final Reading (Test)	832.942	836.750	840.991	847.148			
Initial Reading (Test)	850.728	833.638	837.412	843.443			
Volume, V_T	2.214	3.112	3.579	3.705			
Temp, T_T	76	76	76	76			
Final Reading (Box)	808.996	912.869	917.171	923.353			
Initial Reading (Box)	806.739	909.704	913.546	919.629			
Volume, V_B	2.257	3.165	3.625	3.724			
Temp, T_B	79.5	81	82.5	84			
Elapsed Time, Θ	5	5	4	3			AVG.
ΔH_a	1.43	1.44	1.39	1.45			
γ	.986	.990	.994	1.000			

$$\Delta H_a = \frac{(0.0317)\Delta H}{P_B(T_B + 460)}\left[\frac{(T_T + 460)}{V_T}\Theta\right]^2 \qquad \gamma = \frac{V_T\,(P_B)\,(T_B + 460)}{V_B\,\left(P_B + \frac{\Delta H}{13.6}\right)\,(T_T + 460)}$$

CALIBRATION PERFORMED BY Jeff Smith

ETS119

ETS, INC.

METER CONSOLE CALIBRATION FORM

Meter Box No. 1 Nutech Barometric Pressure, P_B 29.97 in.Hg

Test Meter No. ______ Date 6-26-81

Run No.	1	2	3	4	5	6	
Orifice Setting, ΔH	.5	1	2	4	8		
Final Reading (Test)	131.598	134.732	138.223	141.972	152.397		
Initial Reading (Test)	129.571	131.939	135.069	138.692	147.828		
Volume, V_T	2.027	2.793	3.154	3.280	4.569		
Temp, T_T	73	73	73	73	74		
Final Reading (Box)	33.484	36.630	40.137	43.897	54.259		
Initial Reading (Box)	31.439	33.820	36.967	40.609	49.711		
Volume, V_B	2.045	2.810	3.170	3.288	4.548		
Temp, T_B	82.5	82.5	83.5	84	88.5		
Elapsed Time, Θ	5	5	4	3	3		AVG.
ΔH_a	1.82	1.78	1.78	1.85	1.90		
γ	1.007	1.010	1.010	1.009	1.007		

$$\Delta H_a = \frac{(0.0317)\Delta H}{P_B(T_B + 460)}\left[\frac{(T_T + 460)}{V_T}\Theta\right]^2 \qquad \gamma = \frac{V_T\,(P_B)\,(T_B + 460)}{V_B\,(P_B + \frac{\Delta H}{13.6})\,(T_T + 460)}$$

CALIBRATION PERFORMED BY Jeff Smith

ETS119

ETS, INC.

METER CONSOLE CALIBRATION FORM

Meter Box No. 2 Nutech Barometric Pressure, P_B 29.95 in.Hg

Test Meter No. ______ Date 6-26-81

Run No.	1	2	3	4	5	6	
Orifice Setting, ΔH							
Final Reading (Test)	425.492	428.735	432.374	436.236	441.639		
Initial Reading (Test)	423.421	425.862	429.107	432.835	436.912		
Volume, V_T	2.071	2.873	3.267	3.401	4.727		
Temp, T_T	75	75	75	75	75		
Final Reading (Box)	61.021	64.362	68.126	72.115	77.659		
Initial Reading (Box)	58.902	61.402	64.748	68.606	72.811		
Volume, V_B	2.119	2.960	3.378	3.509	4.848		
Temp, T_B	86	88.5	91.5	94	98		
Elapsed Time, Θ	5	5	4	3	3		AVG.
ΔH_a	1.62	1.67	1.65	1.70	1.75		
γ	.992	.992	.992	.994	.987		

$$\Delta H_a = \frac{(0.0317)\Delta H}{P_B(T_B + 460)}\left[\frac{(T_T + 460)}{V_T}\Theta\right]^2 \qquad \gamma = \frac{V_T\,(P_B)\,(T_B + 460)}{V_B\,(P_B + \frac{\Delta H}{13.6})\,(T_T + 460)}$$

CALIBRATION PERFORMED BY Jeff Smith

ETS, INC.

DRY GAS METER AND ORIFICE
POST TEST CALIBRATION

Date 7/24/81 Jeff

Box No. Nutch #2

Barometric pressure, P_b = 29.98 in. Hg

Dry gas meter No. ______

ΔH = ______ in. H_2O

Vac. = ______

Orifice manometer setting, ΔH, in. H_2O	Gas volume wet test meter V_w, ft_3	Gas volume dry gas meter V_d, ft_3	Temperature Wet test Meter t_w, °F	 Dry gas meter Inlet t_{di}, °F	 Outlet t_{do}, °F	 Average t_d, °F	Time θ, min	γ	ΔH@
.5	2.071	2.117	73	N/A	N/A	85	5		
1	2.875	2.963	73	|	|	88	5		
2	3.264	3.372	73	|	|	90	4		
4	3.397	3.502	73	|	|	93	3		
8	4.724	4.845	73	↓	↓	95	3		
							Average		

Calculations

ΔH	$\frac{\Delta H}{13.6}$	γ $\frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)\left(t_w + 460\right)}$	ΔH@ $\frac{0.0317 \Delta H}{P_b (t_d + 460)} \left[\frac{(t_w + 460)\theta}{V_w}\right]^2$
.5	0.0368	.999	1.61
1	0.0735	.995	1.66
2	0.1471	.994	1.64
4	0.2941	.997	169
8	0.5882	.996	1.71

γ = Ratio of accuracy of wet test meter to dry test meter. Tolerance = ± 0.01

ΔH@ = Orifice pressure differential that gives 0.75 cfm of air at 70 F and 29.92 inches of mercury, in. H_2O. Tolerance - ± 0.15

ETS121

ETS, INC.

DRY GAS METER AND ORIFICE POST TEST CALIBRATION

Date 7/24/81 Jeff Smith

Box No. Notech #1

Barometric pressure, P_b = 29.86 in. Hg

Dry gas meter No. ______

ΔH = ______ in. H_2O

Vac. = ______

Orifice manometer setting, ΔH, in. H_2O	Gas volume wet test meter V_w, ft_3	Gas volume dry gas meter V_d, ft_3	Temperature: Wet test: Meter t_w, °F	Temperature: Dry gas meter: Inlet t_{di}, °F	Temperature: Dry gas meter: Outlet t_{do}, °F	Temperature: Dry gas meter: Average t_d, °F	Time θ, min	γ	ΔH@
.5	2.023	2.033	72	N/A	N/A	79	5	1.007	
1	2.788	2.806	72	↓	↓	80	5		
2	3.155	3.172	72			80	4		
4	3.281	3.285	72			80	3		
8	4.544	4.569	72			81	3		
						Average			

Calculations

		γ	ΔH@
ΔH	$\frac{\Delta H}{13.6}$	$\frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)}$	$\frac{0.0317 \Delta H}{P_b (t_d + 460)} \left[\frac{(t_w + 460)\theta}{V_w}\right]^2$
.5	0.03676	1.007	1.703
1	0.0735	1.006	1.790
2	0.1471	1.005	1.790
4	0.29412	1.004	1.861
8	0.58824	0.9918	1.937

γ = Ratio of accuracy of wet test meter to dry test meter. Tolerance = ± 0.01

ΔH@ = Orifice pressure differential that gives 0.75 cfm of air at 70 F and 29.92 inches of mercury, in. H_2O. Tolerance - ± 0.15

ETS121

PITOT TUBE IDENTIFICATION NUMBER: 10 DATE: 6/26/81

CALIBRATED BY: RODNEY A. GIBSON

	"A" SIDE CALIBRATION			
RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(A)$
1	0.29	0.42	.82	-0.01
2	0.45	0.62	.84	+0.01
3	0.10	0.14	.84	+0.01
		$\bar{C}_p$ (SIDE A)	.83	

	"B" SIDE CALIBRATION			
RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(B)$
1	0.29	0.42	.82	-0.01
2	0.45	0.62	.84	+0.01
3	0.10	0.14	.84	+0.01
		$\bar{C}_p$ (SIDE B)	.83	

$$\text{AVERAGE DEVIATION} = \sigma(\text{A OR B}) = \frac{\sum_{1}^{3} \left| C_p(s) - \bar{C}_p(\text{A OR B}) \right|}{3} \longleftarrow \text{MUST BE} < 0.01$$

$$\left| \bar{C}_p(\text{SIDE A}) - \bar{C}_p(\text{SIDE B}) \right| \longleftarrow \text{MUST BE} < 0.01$$

Figure 2-9. Pitot tube calibration data.

$$C_{p(s)} = C_{p(std)} \sqrt{\frac{\Delta p_{std}}{\Delta p_s}}$$

Equation 2-2

where:

$C_{p(s)}$ = Type S pilot tube coefficient

$C_{p(std)}$ = Standard pitot tube coefficient; use 0.99 if the coefficient is unknown and the tube is designed according to the criteria of Sections 2.7.1 to 2.7.5 of this method.

Δp_{std} = Velocity head measured by the standard pitot tube, cm H_2O (in. H_2O)

Δp_s = Velocity head measured by the Type S pitot tube, cm H_2O (in. H_2O)

4.1.4.2 Calculate $\bar{C}_p$ (side A), the mean A-side coefficient, and $\bar{C}_p$ (side B), the mean B-side coefficient; calculate the difference between these two average values.

4.1.4.3 Calculate the deviation of each of the three A-side values of $C_{p(s)}$ from $\bar{C}_p$ (side A), and the deviation of each B-side value of $C_{p(s)}$ from $\bar{C}_p$ (side B). Use the following equation:

$$\text{Deviation} = C_{p(s)} - \bar{C}_p(\text{A or B})$$

Equation 2-3

4.1.4.4 Calculate σ, the average deviation from the mean, for both the A and B sides of the pitot tube. Use the following equation:

$$\sigma(\text{side A or B}) = \frac{\sum_{1}^{3} |C_{p(s)} - \bar{C}_p(A \text{ or } B)|}{3}$$

Equation 2-4

4.1.4.5 Use the Type S pitot tube only if the values of σ (side A) and σ (side B) are less than or equal to 0.01 and if the absolute value of the difference between $\bar{C}_p$ (A) and $\bar{C}_p$ (B) is 0.01 or less.

4.1.5 Special considerations.

4.1.5.1 Selection of calibration point.

4.1.5.1.1 When an isolated Type S pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The Type S pitot coefficients so obtained, i.e., $\bar{C}_p$ (side A) and $\bar{C}_p$ (side B), will be valid, so long as either: (1) the isolated pitot tube is used; or (2) the pitot tube is used with other components (nozzle, thermocouple, sample probe) in an arrangement that is free from aerodynamic interference effects (see Figures 2-6 through 2-8).

4.1.5.1.2 For Type S pitot tube-thermocouple combinations (without sample probe), select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The coefficients so obtained will be valid so long as the pitot tube-thermocouple combination is used by itself or with other components in an interference-free arrangement (Figures 2-6 and 2-8).

4.1.5.1.3 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe sheath into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 9 in Section 6). Therefore, to minimize the blockage effect, the calibration point may be a few inches off-center if necessary. The actual blockage effect will be negligible when the theoretical blockage, as determined by a projected-area model of the probe sheath, is 2 percent or less of the duct cross-sectional area for assemblies without external sheaths (Figure 2-10a), and 3 percent or less for assemblies with external sheaths (Figure 2-10b).

4.1.5.2 For those probe assemblies in which pitot tube-nozzle interference is a factor (i.e., those in which the pitot-nozzel separation distance fails to meet the specification illustrated in Figure 2-6a), the value of $C_{p(s)}$ depends upon the amount of free-space between the tube and nozzle, and therefore is a function of nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used nozzle sizes in place. Note that the single-velocity calibration technique is acceptable for this purpose, even though the larger nozzle sizes (>0.635 cm or ¼ in.) are not ordinarily used for isokinetic sampling at velocities around 915 m/min (3,000 ft/min), which is the calibration velocity; note also that it is not necessary to draw an isokinetic sample during calibration (see Citation 19 in Section 6).

4.1.5.3 For a probe assembly constructed such that its pitot tube is always used in the same orientation, only one side of the pitot tube need be calibrated (the side which will face the flow). The pitot tube must still meet the alignment specifications of Figure 2-2 or 2-3, however, and must have an average deviation (σ) value of 0.01 or less (see Section 4.1.4.4).

PITOT TUBE IDENTIFICATION NUMBER: 13 **DATE:** 6/26/81
CALIBRATED BY: RODNEY A. GIBSON

	"A" SIDE CALIBRATION			
RUN NO.	**Δp_{std} cm H_2O (in. H_2O)**	**$\Delta p_{(s)}$ cm H_2O (in. H_2O)**	**$C_{p(s)}$**	**DEVIATION $C_{p(s)} - \bar{C}_p(A)$**
1	0.30	0.42	0.84	0
2	0.45	0.62	0.84	0
3	0.11	0.15	0.85	.01
		$\bar{C}_p$ (SIDE A)	0.84	

	"B" SIDE CALIBRATION			
RUN NO.	**Δp_{std} cm H_2O (in. H_2O)**	**$\Delta p_{(s)}$ cm H_2O (in. H_2O)**	**$C_{p(s)}$**	**DEVIATION $C_{p(s)} - \bar{C}_p(B)$**
1	0.30	0.42	0.84	0
2	0.45	0.62	0.84	0
3	0.11	0.15	0.85	-.01
		$\bar{C}_p$ (SIDE B)	0.84	

$$\text{AVERAGE DEVIATION} = \sigma(\text{A OR B}) = \frac{\sum_{1}^{3} \left| C_p(s) - \bar{C}_p(\text{A OR B}) \right|}{3} \leftarrow \text{MUST BE} < 0.01$$

$$\left| \bar{C}_p(\text{SIDE A}) - \bar{C}_p(\text{SIDE B}) \right| \leftarrow \text{MUST BE} < 0.01$$

Figure 2-9. Pitot tube calibration data.

$$C_{p(s)} = C_{p(std)} \sqrt{\frac{\Delta p_{std}}{\Delta p_s}}$$

Equation 2-2

where:

$C_{p(s)}$ = Type S pitot tube coefficient
$C_{p(std)}$ = Standard pitot tube coefficient; use 0.99 if the coefficient is unknown and the tube is designed according to the criteria of Sections 2.7.1 to 2.7.5 of this method.
Δp_{std} = Velocity head measured by the standard pitot tube, cm H_2O (in. H_2O)
Δp_s = Velocity head measured by the Type S pitot tube, cm H_2O (in. H_2O)

4.1.4.2 Calculate $\bar{C}_p$ (side A), the mean A-side coefficient, and $\bar{C}_p$ (side B), the mean B-side coefficient; calculate the difference between these two average values.

4.1.4.3 Calculate the deviation of each of the three A-side values of $C_{p(s)}$ from $\bar{C}_p$ (side A), and the deviation of each B-side value of $C_{p(s)}$ from $\bar{C}_p$ (side B). Use the following equation:

$$\text{Deviation} = C_{p(s)} - \bar{C}_p(\text{A or B})$$

Equation 2-3

4.1.4.4 Calculate σ, the average deviation from the mean, for both the A and B sides of the pitot tube. Use the following equation:

$$\sigma\,(\text{side A or B}) = \frac{\sum_{1}^{3} \left| C_{p(s)} - \bar{C}_p(A \text{ or } B) \right|}{3}$$

Equation 2-4

4.1.4.5 Use the Type S pitot tube only if the values of σ (side A) and σ (side B) are less than or equal to 0.01 and if the absolute value of the difference between $\bar{C}_p$ (A) and $\bar{C}_p$ (B) is 0.01 or less.

4.1.5 Special considerations.

4.1.5.1 *Selection of calibration point.*

4.1.5.1.1 When an isolated Type S pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The Type S pitot coefficients so obtained, i.e., $\bar{C}_p$ (side A) and $\bar{C}_p$ (side B), will be valid, so long as either: (1) the isolated pitot tube is used; or (2) the pitot tube is used with other components (nozzle, thermocouple, sample probe) in an arrangement that is free from aerodynamic interference effects (see *Figures* 2-6 through 2-8).

4.1.5.1.2 For Type S pitot tube-thermocouple combinations (without sample probe), select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The coefficients so obtained will be valid so long as the pitot tube-thermocouple combination is used by itself or with other components in an interference-free arrangement (Figures 2-6 and 2-8).

4.1.5.1.3 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe sheath into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 9 in Section 6). Therefore, to minimize the blockage effect, the calibration point may be a few inches off-center if necessary. The actual blockage effect will be negligible when the theoretical blockage, as determined by a projected-area model of the probe sheath, is 2 percent or less of the duct cross-sectional area for assemblies without external sheaths (Figure 2-10a), and 3 percent or less for assemblies with external sheaths (*Figure* 2-10b).

4.1.5.2 For those probe assemblies in which pitot tube-nozzle interference is a factor (i.e., those in which the pitot-nozzel separation distance fails to meet the specification illustrated in *Figure* 2-6a), the value of $C_{p(s)}$ depends upon the amount of free-space between the tube and nozzle, and therefore is a function of nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used nozzle sizes in place. Note that the single-velocity calibration technique is acceptable for this purpose, even though the larger nozzle sizes (>0.635 cm or ¼ in.) are not ordinarily used for isokinetic sampling at velocities around 915 m/min (3,000 ft/min), which is the calibration velocity; note also that it is not necessary to draw an isokinetic sample during calibration (see Citation 19 in Section 6).

4.1.5.3 For a probe assembly constructed such that its pitot tube is always used in the same orientation, only one side of the pitot tube need be calibrated (the side which will face the flow). The pitot tube must still meet the alignment specifications of Figure 2-2 or 2-3, however, and must have an average deviation (σ) value of 0.01 or less (see Section 4.1.4.4).

PITOT TUBE IDENTIFICATION NUMBER: 10 DATE: 7/24/81

CALIBRATED BY: Rodney A. Gibson

"A" SIDE CALIBRATION

RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(A)$
1	0.29	0.42	.82	-.01
2	0.45	0.62	.84	+.01
3	0.11	0.16	.82	-.01
		$\bar{C}_p$ (SIDE A)	.83	

"B" SIDE CALIBRATION

RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(B)$
1	0.29	0.42	.82	-.01
2	0.45	0.62	.84	.01
3	0.11	0.16	.82	-.01
		$\bar{C}_p$ (SIDE B)	.83	

$$\text{AVERAGE DEVIATION} = \sigma(\text{A OR B}) = \frac{\sum_{1}^{3} \left| C_{p(s)} - \bar{C}_p(\text{A OR B}) \right|}{3} \longleftarrow \text{MUST BE} \le 0.01$$

$$\left| \bar{C}_p(\text{SIDE A}) - \bar{C}_p(\text{SIDE B}) \right| \longleftarrow \text{MUST BE} < 0.01$$

Figure 2-9. Pitot tube calibration data.

$$C_{p(s)} = C_{p(std)} \sqrt{\frac{\Delta p_{std}}{\Delta p_s}}$$

Equation 2-2

where:

$C_{p(s)}$ = Type S pitot tube coefficient

$C_{p(std)}$ = Standard pitot tube coefficient; use 0.99 if the coefficient is unknown and the tube is designed according to the criteria of Sections 2.7.1 to 2.7.5 of this method.

Δp_{std} = Velocity head measured by the standard pitot tube, cm H_2O (in. H_2O)

Δp_s = Velocity head measured by the Type S pitot tube, cm H_2O (in. H_2O)

4.1.4.2 Calculate $\bar{C}_p$ (side A), the mean A-side coefficient, and $\bar{C}_p$ (side B), the mean B-side coefficient; calculate the difference between these two average values.

4.1.4.3 Calculate the deviation of each of the three A-side values of $C_{p(s)}$ from $\bar{C}_p$ (side A), and the deviation of each B-side value of $C_{p(s)}$ from $\bar{C}_p$ (side B). Use the following equation:

$$\text{Deviation} = C_{p(s)} - \bar{C}_p(\text{A or B})$$

Equation 2-3

4.1.4.4 Calculate σ, the average deviation from the mean, for both the A and B sides of the pitot tube. Use the following equation:

$$\sigma\,(\text{side A or B}) = \frac{\sum_{1}^{3} |C_{p(s)} - \bar{C}_p(A \text{ or } B)|}{3}$$

Equation 2-4

4.1.4.5 Use the Type S pitot tube only if the values of σ (side A) and σ (side B) are less than or equal to 0.01 and if the absolute value of the difference between $\bar{C}_p$ (A) and $\bar{C}_p$ (B) is 0.01 or less.

4.1.5 Special considerations.

4.1.5.1 Selection of calibration point.

4.1.5.1.1 When an isolated Type S pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The Type S pitot coefficients so obtained, i.e., $\bar{C}_p$ (side A) and $\bar{C}_p$ (side B), will be valid, so long as either: (1) the isolated pitot tube is used; or (2) the pitot tube is used with other components (nozzle, thermocouple, sample probe) in an arrangement that is free from aerodynamic interference effects (see Figures 2-5 through 2-8).

4.1.5.1.2 For Type S pitot tube-thermocouple combinations (without sample probe), select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The coefficients so obtained will be valid so long as the pitot tube-thermocouple combination is used by itself or with other components in an interference-free arrangement (Figures 2-5 and 2-8).

4.1.5.1.3 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe sheath into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 9 in Section 6). Therefore, to minimize the blockage effect, the calibration point may be a few inches off-center if necessary. The actual blockage effect will be negligible when the theoretical blockage, as determined by a projected-area model of the probe sheath, is 2 percent or less of the duct cross-sectional area for assemblies without external sheaths (Figure 2-10a), and 3 percent or less for assemblies with external sheaths (Figure 2-10b).

4.1.5.2 For those probe assemblies in which pitot tube-nozzle interference is a factor (i.e., those in which the pitot-nozzle separation distance fails to meet the specification illustrated in Figure 2-6a), the value of $C_{p(s)}$ depends upon the amount of free-space between the tube and nozzle, and therefore is a function of nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used nozzle sizes in place. Note that the single-velocity calibration technique is acceptable for this purpose, even though the larger nozzle sizes (>0.635 cm or ¼ in.) are not ordinarily used for isokinetic sampling at velocities around 915 m/min (3,000 ft/min), which is the calibration velocity; note also that it is not necessary to draw an isokinetic sample during calibration (see Citation 19 in Section 6).

4.1.5.3 For a probe assembly constructed such that its pitot tube is always used in the same orientation, only one side of the pitot tube need be calibrated (the side which will face the flow). The pitot tube must still meet the alignment specifications of Figure 2-2 or 2-3, however, and must have an average deviation (σ) value of 0.01 or less (see Section 4.1.4.4).

PITOT TUBE IDENTIFICATION NUMBER: 13 **DATE:** 7/24/81
CALIBRATED BY: Rodney A. Gibson

"A" SIDE CALIBRATION

RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(A)$
1	0.30	0.41	.85	+.01
2	0.46	0.62	.85	+.01
3	0.12	0.17	.83	-.01
		$\bar{C}_p$ (SIDE A)	.84	

"B" SIDE CALIBRATION

RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(B)$
1	0.30	0.42	.84	0
2	0.46	0.62	.85	+.01
3	0.12	0.17	.83	-.01
		$\bar{C}_p$ (SIDE B)	.84	

$$\text{AVERAGE DEVIATION} = \sigma (\text{A OR B}) = \frac{\sum_{1}^{3} \left| C_p(s) - \bar{C}_p(\text{A OR B}) \right|}{3} \longleftarrow \text{MUST BE} < 0.01$$

$$\left| \bar{C}_p (\text{SIDE A}) - \bar{C}_p (\text{SIDE B}) \right| \longleftarrow \text{MUST BE} < 0.01$$

Figure 2-9. Pitot tube calibration data.

$$C_{p(s)} = C_{p(std)} \sqrt{\frac{\Delta p_{std}}{\Delta p_s}}$$

Equation 2-2

where:

$C_{p(s)}$ = Type S pitot tube coefficient
$C_{p(std)}$ = Standard pitot tube coefficient; use 0.99 if the coefficient is unknown and the tube is designed according to the criteria of Sections 2.7.1 to 2.7.5 of this method.
Δp_{std} = Velocity head measured by the standard pitot tube, cm H_2O (in. H_2O)
Δp_s = Velocity head measured by the Type S pitot tube, cm H_2O (in. H_2O)

4.1.4.2 Calculate $\bar{C}_p$ (side A), the mean A-side coefficient, and $\bar{C}_p$ (side B), the mean B-side coefficient; calculate the difference between these two average values.

4.1.4.3 Calculate the deviation of each of the three A-side values of $C_{p(s)}$ from $\bar{C}_p$ (side A), and the deviation of each B-side value of $C_{p(s)}$ from $\bar{C}_p$ (side B). Use the following equation:

$$\text{Deviation} = C_{p(s)} - \bar{C}_p(\text{A or B})$$

Equation 2-3

4.1.4.4 Calculate σ, the average deviation from the mean, for both the A and B side of the pitot tube. Use the following equation:

$$\sigma\,(\text{side A or B}) = \frac{\sum_{1}^{3} |C_{p(s)} - \bar{C}_p(A \text{ or } B)|}{3}$$

Equation 2-4

4.1.4.5 Use the Type S pitot tube only if the values of σ (side A) and σ (side B) are less than or equal to 0.01 and if the absolute value of the difference between $\bar{C}_p$ (A) and $\bar{C}_p$ (B) is 0.01 or less.

4.1.5 Special considerations.

4.1.5.1 Selection of calibration point.

4.1.5.1.1 When an isolated Type S pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The Type S pitot coefficients so obtained, i.e., $\bar{C}_p$ (side A) and $\bar{C}_p$ (side B), will be valid, so long as either: (1) the isolated pitot tube is used; or (2) the pitot tube is used with other components (nozzle, thermocouple, sample probe) in an arrangement that is free from aerodynamic interference effects (see Figures 2-6 through 2-8).

4.1.5.1.2 For Type S pitot tube-thermocouple combinations (without sample probe), select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The coefficients so obtained will be valid so long as the pitot tube-thermocouple combination is used by itself or with other components in an interference-free arrangement (Figures 2-6 and 2-8).

4.1.5.1.3 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe sheath into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 9 in Section 6). Therefore, to minimize the blockage effect, the calibration point may be a few inches off-center if necessary. The actual blockage effect will be negligible when the theoretical blockage, as determined by a projected-area model of the probe sheath, is 2 percent or less of the duct cross-sectional area for assemblies without external sheaths (Figure 2-10a), and 3 percent or less for assemblies with external sheaths (Figure 2-10b).

4.1.5.2 For those probe assemblies in which pitot tube-nozzle interference is a factor (i.e., those in which the pitot-nozzle separation distance fails to meet the specification illustrated in Figure 2-6a), the value of $C_{p(s)}$ depends upon the amount of free-space between the tube and nozzle, and therefore is a function of nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used nozzle sizes in place. Note that the single-velocity calibration technique is acceptable for this purpose, even though the larger nozzle sizes (>0.635 cm or ¼ in.) are not ordinarily used for isokinetic sampling at velocities around 915 m/min (3,000 ft/min), which is the calibration velocity; note also that it is not necessary to draw an isokinetic sample during calibration (see Citation 19 in Section 6).

4.1.5.3 For a probe assembly constructed such that its pitot tube is always used in the same orientation, only one side of the pitot tube need be calibrated (the side which will face the flow). The pitot tube must still meet the alignment specifications of Figure 2-2 or 2-3, however, and must have an average deviation (σ) value of 0.01 or less (see Section 4.1.4.4).

APPENDIX 9

Computer Printouts

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RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      RUN 2 OUTLET
DATE OF RUN                                     07/09/81
TIME AT BEGINNING OF RUN                         930
TIME AT END OF RUN                              1130
DN             SAMPLING NOZZLE DIAMETER         .202 IN.
PBAR           BAROMETRIC PRESSURE              27.2 IN.HG.ABS.
TT             NET TIME OF TEST                 120 MIN.
VMN            SAMPLE GAS VOLUME                91.1299 CU.FT.
TM             AVG.GAS METER TEMPERATURE        87.1 DEGR.F.
DH             AVG. ORIFICE PRESSURE DROP        1.59 IN.H2O
VMSTD          VOLUME OF DRY GAS SAMPLED        79.785 DSCF

VLC            H2O FM IMPING. SILICA GEL         199.4 ML
VWSTD          H2O COLLECTED AT STD.COND.          9.416 STD.CU.FT.
BWS            STACK GAS MOISTURE BY VOL.        10.6 PERCENT
               CO2 IN DRY STACK GASES            11.6 PERCENT
               O2 IN DRY STACK GASES              6.5 PERCENT
               CO IN DRY STACK GASES              0.0 PERCENT
               N2 IN DRY STACK GASES             81.9 PERCENT
MFDG           MOL FRACTION OF DRY GAS            0.89
EA             EXCESS AIR                        42.98 PERCENT
MS             MOL WGT OF STACK GAS,WET          28.84

SA             STACK AREA                        48280.6 SQ.IN.
P2             STATIC PRESSURE OF STACK GAS         0.06 IN.HG.ABS.
PSA            STACK GAS PRESSURE                  27.26 IN.HG.ABS.
TS             AVG.STACK TEMPERATURE              323.2 DEGR.F.
VS             STACK GAS VELOC.,STACK COND.      5108 AFPM
QS             STACK GAS VOL.,DRY STD.COND.     %944245 DSCFM
QA             STACK GAS VOLUME,STACK COND.     %1712460 ACFM

I              ISOKINETIC RATIO                 105.8 PERCENT
```

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NOZZLE AND THIMBLE              GRAMS             0.0000
                                GRAINS/ACF        0.0000
                                GRAINS/SCF        0.0000
                                LB/HR-CONC        0.00
                                LB/HR-AREA        0.00
                                LB/HR-AVG         0.00

PROBE                           GRAMS             0.0223
TOTAL-ABOVE ITEMS               GRAMS             0.0223
                                GRAINS/ACF        0.0024
                                GRAINS/SCF        0.0043
                                LB/HR-CONC       34.83
                                LB/HR-AREA       36.98
                                LB/HR-AVG        35.91

FILTER                          GRAMS             0.0000
TOTAL-ABOVE ITEMS               GRAMS             0.0223
                                GRAINS/ACF        0.0024
                                GRAINS/SCF        0.0043
                                LB/HR-CONC       34.83
                                LB/HR-AREA       36.98
                                LB/HR-AVG        35.91

TOTAL-INCL.IMPINGER CATCH     GRAMS             0.0223
                                GRAINS/ACF        0.0024
                                GRAINS/SCF        0.0043
                                LB/HR-CONC       34.83
                                LB/HR-AREA       36.98
                                LB/HR-AVG        35.91
```

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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 07/09/81 PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                     RUN 3 OUTLET
DATE OF RUN                                    07/09/81
TIME AT BEGINNING OF RUN                        1530
TIME AT END OF RUN                              1730
DN              SAMPLING NOZZLE DIAMETER        .202 IN.
PBAR            BAROMETRIC PRESSURE             27 IN.HG.ABS.
TT              NET TIME OF TEST                120 MIN.
VMN             SAMPLE GAS VOLUME               90.4999 CU.FT.
TM              AVG.GAS METER TEMPERATURE      90.8 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP      1.50 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED      78.107 DSCF


VLC             H2O FM IMPING. SILICA GEL       275 ML
VWSTD           H2O COLLECTED AT STD.COND.      12.986 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.      14.3 PERCENT
                CO2 IN DRY STACK GASES          11.6 PERCENT
                O2 IN DRY STACK GASES            6.5 PERCENT
                CO IN DRY STACK GASES            0.0 PERCENT
                N2 IN DRY STACK GASES           81.9 PERCENT
MFDG            MOL FRACTION OF DRY GAS          0.86
EA              EXCESS AIR                      42.98 PERCENT
MS              MOL WGT OF STACK GAS,WET        28.39


SA              STACK AREA                      48280.6 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS       0.06 IN.HG.ABS.
PSA             STACK GAS PRESSURE                27.06 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE            323.2 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.    5184 AFPM
QS              STACK GAS VOL.,DRY STD.COND.   %911922 DSCFM
QA              STACK GAS VOLUME,STACK COND.   %1737950 ACFM


I               ISOKINETIC RATIO               107.2 PERCENT
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NOZZLE AND THIMBLE               GRAMS             0.0000
                                 GRAINS/ACF        0.0000
                                 GRAINS/SCF        0.0000
                                 LB/HR-CONC        0.00
                                 LB/HR-AREA        0.00
                                 LB/HR-AVG         0.00


PROBE                            GRAMS             0.0216
TOTAL-ABOVE ITEMS                GRAMS             0.0216
                                 GRAINS/ACF        0.0022
                                 GRAINS/SCF        0.0043
                                 LB/HR-CONC       33.28
                                 LB/HR-AREA       35.82
                                 LB/HR-AVG        34.55


FILTER                           GRAMS             0.0000
TOTAL-ABOVE ITEMS                GRAMS             0.0216
                                 GRAINS/ACF        0.0022
                                 GRAINS/SCF        0.0043
                                 LB/HR-CONC       33.28
                                 LB/HR-AREA       35.82
                                 LB/HR-AVG        34.55


TOTAL-INCL.IMPINGER CATCH      GRAMS             0.0216
                                 GRAINS/ACF        0.0022
                                 GRAINS/SCF        0.0043
                                 LB/HR-CONC       33.28
                                 LB/HR-AREA       35.82
                                 LB/HR-AVG        34.55
```

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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 07/09/81 PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                   RUN 4 INLET
DATE OF RUN                                  07/09/81
TIME AT BEGINNING OF RUN                      2150
TIME AT END OF RUN                            2250
DN             SAMPLING NOZZLE DIAMETER       .202 IN.
PBAR           BAROMETRIC PRESSURE            26.94 IN.HG.ABS.
TT             NET TIME OF TEST               60 MIN.
VMN            SAMPLE GAS VOLUME              44.127 CU.FT.
TM             AVG.GAS METER TEMPERATURE     83.4 DEGR.F.
DH             AVG. ORIFICE PRESSURE DROP     1.54 IN.H2O
VMSTD          VOLUME OF DRY GAS SAMPLED     38.521 DSCF

VLC            H2O FM IMPING. SILICA GEL      98 ML
VWSTD          H2O COLLECTED AT STD.COND.      4.628 STD.CU.FT.
BWS            STACK GAS MOISTURE BY VOL.     10.7 PERCENT
               CO2 IN DRY STACK GASES         11.6 PERCENT
               O2 IN DRY STACK GASES           6.5 PERCENT
               CO IN DRY STACK GASES           0.0 PERCENT
               N2 IN DRY STACK GASES          81.9 PERCENT
MFDG           MOL FRACTION OF DRY GAS         0.89
EA             EXCESS AIR                     42.98 PERCENT
MS             MOL WGT OF STACK GAS,WET       28.82

SA             STACK AREA                     48280.6 SQ.IN.
P2             STATIC PRESSURE OF STACK GAS       0.06 IN.HG.ABS.
PSA            STACK GAS PRESSURE                27.00 IN.HG.ABS.
TS             AVG.STACK TEMPERATURE            341.0 DEGR.F.
VS             STACK GAS VELOC.,STACK COND.   5301 AFPM
QS             STACK GAS VOL.,DRY STD.COND.  %947257 DSCFM
QA             STACK GAS VOLUME,STACK COND.  %1777280 ACFM

I              ISOKINETIC RATIO              101.8 PERCENT
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NOZZLE AND THIMBLE                GRAMS             2.2398
                                  GRAINS/ACF        0.4772
                                  GRAINS/SCF        0.8954
                                  LB/HR-CONC       %7269.16
                                  LB/HR-AREA       %7428.82
                                  LB/HR-AVG        %7348.99


PROBE                             GRAMS             0.1858
TOTAL-ABOVE ITEMS                 GRAMS             2.4256
                                  GRAINS/ACF        0.5167
                                  GRAINS/SCF        0.9697
                                  LB/HR-CONC       %7872.01
                                  LB/HR-AREA       %8044.91
                                  LB/HR-AVG        %7958.46


FILTER                            GRAMS             0.0000
TOTAL-ABOVE ITEMS                 GRAMS             2.4256
                                  GRAINS/ACF        0.5167
                                  GRAINS/SCF        0.9697
                                  LB/HR-CONC       %7872.01
                                  LB/HR-AREA       %8044.91
                                  LB/HR-AVG        %7958.46


TOTAL-INCL.IMPINGER CATCH       GRAMS             2.4256
                                  GRAINS/ACF        0.5167
                                  GRAINS/SCF        0.9697
                                  LB/HR-CONC       %7872.01
                                  LB/HR-AREA       %8044.91
                                  LB/HR-AVG        %7958.46
```

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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 07/10/81 PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      RUN 5 OUTLET
DATE OF RUN                                     07/10/81
TIME AT BEGINNING OF RUN                         1020
TIME AT END OF RUN                               1220
DN              SAMPLING NOZZLE DIAMETER         .202 IN.
PBAR            BAROMETRIC PRESSURE              26.98 IN.HG.ABS.
TT              NET TIME OF TEST                 120 MIN.
VMN             SAMPLE GAS VOLUME                88.317 CU.FT.
TM              AVG.GAS METER TEMPERATURE       94.3 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP       1.47 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED       75.674 DSCF


VLC             H2O FM IMPING. SILICA GEL        182.6 ML
VWSTD           H2O COLLECTED AT STD.COND.        8.623 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.       10.2 PERCENT
                CO2 IN DRY STACK GASES           11.6 PERCENT
                O2 IN DRY STACK GASES             6.5 PERCENT
                CO IN DRY STACK GASES             0.0 PERCENT
                N2 IN DRY STACK GASES            81.9 PERCENT
MFDG            MOL FRACTION OF DRY GAS           0.90
EA              EXCESS AIR                       42.98 PERCENT
MS              MOL WGT OF STACK GAS,WET         28.88


SA              STACK AREA                       48280.6 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS        0.07 IN.HG.ABS.
PSA             STACK GAS PRESSURE                 27.05 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE             322.6 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.     5094 AFPM
QS              STACK GAS VOL.,DRY STD.COND.    %938412 DSCFM
QA              STACK GAS VOLUME,STACK COND.    %1707690 ACFM


I               ISOKINETIC RATIO                100.9 PERCENT
```

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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  07/10/81 PAGE 3


NOZZLE AND THIMBLE                GRAMS              0.0000
                                  GRAINS/ACF         0.0000
                                  GRAINS/SCF         0.0000
                                  LB/HR-CONC         0.00
                                  LB/HR-AREA         0.00
                                  LB/HR-AVG          0.00


PROBE                             GRAMS              0.0069
TOTAL-ABOVE ITEMS                 GRAMS              0.0069
                                  GRAINS/ACF         0.0008
                                  GRAINS/SCF         0.0014
                                  LB/HR-CONC        11.29
                                  LB/HR-AREA        11.44
                                  LB/HR-AVG         11.37


FILTER                            GRAMS              0.0002
TOTAL-ABOVE ITEMS                 GRAMS              0.0071
                                  GRAINS/ACF         0.0008
                                  GRAINS/SCF         0.0014
                                  LB/HR-CONC        11.62
                                  LB/HR-AREA        11.77
                                  LB/HR-AVG         11.70


TOTAL-INCL.IMPINGER CATCH       GRAMS              0.0071
                                  GRAINS/ACF         0.0008
                                  GRAINS/SCF         0.0014
                                  LB/HR-CONC        11.62
                                  LB/HR-AREA        11.77
                                  LB/HR-AVG         11.70
```

APPENDIX 10

Field Audit Report

RESEARCH TRIANGLE INSTITUTE

FIELD AUDIT REPORT

Harrington Unit No. 3
Southwestern Public Service Company
Amarillo, Texas

by

David S. Ensor

Research Triangle Institute
P. O. Box 12194
Research Triangle Park, North Carolina 27709

October 1981

RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

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SECTION 1

INTRODUCTION

The field testing at the Harrington Station Unit No. 3 baghouse required sampling with EPA Method 5 and impactors. The objective of the EPA Method 5 was to evaluate the ability of the baghouses to meet new source performance standards. The tests were conducted during the week of July 6, 1981.

It was the responsibility of Dr. D. S. Ensor of the Research Triangle Institute to provide quality assurance audits on the Method 5 and Orsat measurements. The quality assurance objectives of the project were:

1. To assure reliability of data obtained with EPA Method 5 and Orsat.
2. To provide adequate documentation which would support data validity.

All the tests were conducted at the stack of the No. 3 baghouse. Extra Method 5 tests were conducted to obtain the three acceptable tests, and three cascade impactor tests were conducted. In addition, the baghouse was bypassed to obtain "uncontrolled" conditions.

SECTION 2

APPROACH

The quality assurance efforts were largely directed toward a systems audit of the test work. The audit was limited to the field part of the operation. The following parameters were considered:

1. Presampling procedures.
2. Calibration.
3. Sampling procedures.
4. Sample recovery.
5. Analytical procedures.

The attached field audit data sheets (Appendix A) show the details of the audit.

SECTION 3

RESULTS AND CONCLUSIONS

The testing for Method 5 and Orsat were performed in a satisfactory manner. Care was taken where and when it was needed. The conclusions are as follows:

1. The test work followed the protocol described in Method 4 (Orsat) and Method 5 of the Federal Register.
2. The tests were carefully performed.
3. The crew arrived on-site well equipped, and the equipment was in good repair.

APPENDIX

Quantitative Field Audit Data Sheets

Quantitative Field Audit

METHOD 5 SAMPLING

Site: Harrington
Location: Amarillo Tx

Date: July 9, 1981
Time:
Auditor(s): Cusor

Nominal Duct Gas Composition _____ CO _____ CO_2 _____ O_2
_____ SO_2 _____ particulate
_____ gas temperature _____ gas pressure

A. GENERAL

1. Operators have access to protocol and test methods? yes

2. Data sheets available? yes

3. Equipment in good repair? yes.

B. EQUIPMENT PREPARATION AND CHECK

1. Sampling train assembled and leak checked. yes

2. Probe and filter box heaters checked and set for proper temperatures. yes

3. Stack gas temperature measuring system assembled and checked for proper operation by comparing to a mercury-in-glass thermometer. unknown

4. Stack gas velocity measuring system assembled and checked for proper operation. yes

5. Orsat analyzer assembled and checked. yes

C. PRELIMINARY MEASUREMENTS

1. Selection of traverse points according to Method 1. yes
12 points

2. Moisture content by Method 4, or equivalent. yes

3. Molecular weight by Method 3, or equivalent. yes

4. Measurement of stack dimensions. used stack measurements from plant

5. Mark probe for sampling at traverse points. yes

6. Diameter of nozzle checked. checked by ETS

D. SAMPLE COLLECTION

1. Equal sampling time at each traverse point. yes

2. Probe temperature satisfactory throughout the test. didn't check

3. Filter box temperature 120 ±14° C (248 ±25° F) throughout the test. yes

4. Sample gas temperature at last impinger 20° C (68° F) throughout the test. I didn't check

5. Isokinetic sampling checked and adjusted if necessary at least every 5 minutes. ✓

6. Leak check of sampling train at end of test. yes
   2

E. SAMPLE RECOVERY

1. Satisfactory handling and movement of probe and filter to sample recovery area. yes

2. Recovery area satisfactory (i.e., space, cleanliness, etc.).
   Recovery was done on stack because of difficulty of transport.

3. Sample recovery procedure adequate.
   yes – although they could have used a longer brush

4. Proper labeling of sample containers. yes

5. Determination of moisture content procedure adequate. yes.

F. ANALYSIS

1. Proper equilibration of (a) filter, (b) probe wash residue, and (c) acetone blank residue.

2. Correct collected particulate for acetone blank.
   Said they would.

3. Analytical balance checked before weighings.

G. DOCUMENTATION

1. All information recorded on data sheet as obtained.

2. All unusual conditions recorded.

H. COMMENTS

Quantitative Field Audit

CASCADE IMPACTOR

Site: Harrington

Location: Amarillo Tx

Date: July 9, 1981

Time:

Auditor(s): Ens

Nominal Duct Gas Composition ______ CO ______ CO_2 ______ O_2

______ SO_2 ______ particulate

______ gas temperature ______ gas pressure

A. GENERAL

1. Data sheets and record keeping at test site. fairly good - a note book is needed.

2. Are range-finding runs done? Only to a limited extent because only 4 runs were done

3. Are run times and stage loadings appropriate? This was a major Problem for impactor [illegible]'s

4. Impactors calibrated?

   Source

   Frequency

   Records reviewed

5. Procedures followed by test crew. - yes

B. INPACTOR SET-UP

1. Substrate selection fibre greased

Comments: Apiezon H on stainless steel

2. Substrate handling.

Labeling system. good

Preweighing predonditioning. yes

Stage loading.

3. Impactor handling from assembly to sampling port. good

C. OPERATION

Control device ______________ INLET OUT

Impactor type ______________

1. Leak check: yes cold yes hot

2. Nozzle/velocity calculations/selection. yes

3. Warm-up time 45 minutes.

4. Flow rate: Some what on the high side (acceptable range: ____ to ____)
but was selected by the need for large gas volumes

5. "Blank" impactor? ran initially

6. Orientation (sketch: showing sampling site including impactor orientation). run at stack in NW port at 2nd traverse point

7. Traverse? used M5 data

8. Flow rate minotoring (for consistency, plugging, etc.) The flow rate was constant during the tests and required little attention

9. Orsat test conducted? yes

D. IMPACTOR DISASSEMBLY

1. Impactor handling from sampling port to disassembly.
    a. Transport. good
    b. Cooling/storage. – in water bath

2. Brushdown of nozzle. Used acetone wash and a weighed aluminum cup.

3. Brushdown of impactor. used camel hair brush and established procedures

4. Inspection for re-entrainment. yes.

5. Handling of exposed substrates. used tweezers.

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6. Labeling/identification of stored substrates. labeled petri dish

7. Transportation of substrates to weighing site.
Sealed plastic bag with silica gel

8. Impactor clean-up.
Soap and water with acetone rinse

E. WEIGHING

1. Substrate conditioning - time 24 hrs in desiccator
- conditions pre treatment in oven at 300°F 3 [illegible]

Match with B2b.

2. Balance calibration.

Standard. Class M weights

Frequency. every set

Record. bound note book.

3. Balance checks.

How. weigh to constant weight
check substrate carried to field with

Frequency.

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4. Balance identification.

    Manufacturer.

    Model.

    Characteristics.

5. Record keeping.

    Notebook?

    Data sheets?

6. Reweighing program.

F. DATA REDUCTION

1. General method.

2. Does model match observed field conditions?

3. Using observed data (Q, T, ...).

4. Source of impactor calibration constants.

G. REFERENCE

D. B. Harris
Procedures for Cascade Impactor Calibration and Operation in Process Streams
EPA Report No. EPA-600/2-77-004 (NTIS No. PB 263623), January 1977.